On the way to electromobility – a green(er) but more unequal future?

Edited by
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Béla Galgóczi

1. Fast-track electrification

This overview is based on the findings of a study conducted by the European Trade Union Institute and the European Climate Foundation in 2021 and 2022.

The transition in Europe towards electric cars looks ever-more inevitable and, in the last couple of years, the pace of electrification has been accelerating. Electric car sales in Europe are picking up rapidly as, in the second quarter of 2022, sales of battery electric vehicles[1] (BEVs) accounted for 9.9 per cent of total passenger car registrations, with plug-in hybrid cars (PHEVs) having an 8.7 per cent market share; while sales of diesel and petrol cars plunged by 27 and 22 per cent respectively compared to the same period of 2021 (ACEA 2022).

Europe's objectives on climate, air pollution, energy security and industrial competitiveness are now fully aligned in this direction. Other proposed solutions, such as e-fuels, biofuels or hydrogen, look unlikely to play more than a niche role in our future cars.

In October 2022, EU negotiators reached agreement with Member States on the Commission's original proposal to achieve zero-emission road mobility by 2035, with an EU fleet-wide target of reducing the CO_2 emissions produced by new passenger cars and light commercial vehicles by 100 per cent compared to 2021 (European Parliament 2022). With this step, the era of the internal combustion engine is indeed coming to an end.

Initially, this change was driven by developments in environmental and climate policy going back to the early 1990s. The last 30 years of EU car emissions regulation has been a controversial process with objectives that have zigzagged and frequently been contradictory. Early on, the EU focused on CO_2 emissions (fuel efficiency) but it neglected pollution standards (e.g. NOx) for too long. Industry self-regulation failed to meet the 2008 targets, and stricter and binding criteria followed, but the asymmetry between climate and environmental standards has continued to pave the way for dieselisation

1. Battery electric vehicles (BEVs) have an electric engine only and are powered by a rechargeable battery; hybrid electric vehicles (HEVs) have both an electric engine and a combustion engine but do not have a battery; plug-in hybrid electric vehicles (PHEVs) have engines of both types and a battery. All three are often referred to as electric vehicles (EVs) but only BEVs are fully electric. In electric mode, HEVs and PHEVs also have a very limited range and are seen as an interim stage in vehicle electrification.

and upmarket drift. This trend has been aggravated by lax testing procedures and implementation regimes, with the criminal practices of car manufacturers leading to the Dieselgate scandal. Weight-based CO_2 emissions standards have also contributed to adverse developments as cars have become heavier, more powerful and more expensive, compromising a significant share of the achieved emission reductions. This malfunctioning regulatory framework also resulted, when the European Green Deal had finally been set up, in fast-track electrification remaining the only option to deliver the 100 per cent emissions reduction target by 2035, as set by the 'Fit for 55' package. At the same time, this fast-track transition is increasingly being driven by technology improvements and market forces. If the rapidity of this transition was ever in doubt, the EU ban on Russian oil imports provides further impetus. The train has departed and the journey is gaining momentum.

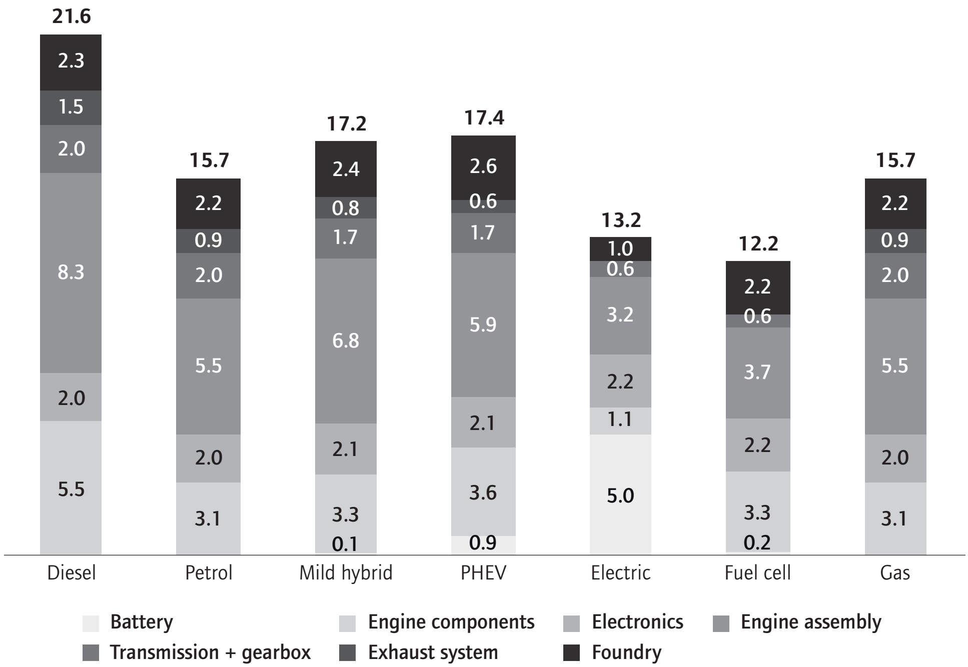
The industry finds itself in a paradigm change: some call it a revolution; others say mobility will cease to exist in the way we know it. It is no exaggeration to say that every job in the mobility sector will be affected in some way.

One key lesson to be drawn from the country reports and cross-cutting analyses produced as a result of this study is that, while the electrification of individual road transport is the focus – that is, the change of the system of propulsion from fossil fuels to clean electricity – the transformation is much more comprehensive. On the one hand, it is clear that the manufacture of battery electric cars is less employment intensive. Based on the findings of the chapter in this volume on France, the labour intensity of a battery electric car is calculated to be 61 per cent when compared to a diesel car, with nearly 40 per cent of that lower labour input linked to the battery, as Figure 1 shows.

The particular challenge for the automotive industry is that many other changes are going on at the same time. Digitalisation of both product and process, automation of production and the complete reorganisation of automotive value chains are also underway. As a result, the employment effects that are due to this deep structural change will be enormous: millions of jobs will disappear while others with completely new job profiles and skills needs are being created. None of the 14 million jobs in the broad industry will remain unaffected.

This paradigm change also means that established incumbent positions that have been built up over decades are being challenged. Newcomers have been able to enter the market in a way that was previously hard to imagine. Past success offers no template for the future. All this has been happening in a new era of deglobalisation, in the wake of supply chain disruptions as a result of the Covid-19 pandemic and due to the end of the post-WW2 rules-based international order, accelerated by Russia's invasion of Ukraine, which has meant that the geopolitical stakes have now become even higher.

Figure 1 **Employment indices by propulsion technology in France (FTE needs for 1000 vehicles)**



Source: Syndex.

The impact on employment of any one strategy is difficult to determine. Forecast results depend on the scope of the analysis (narrow or broad automotive industry, or whole economy); assumptions about developments in sales volume and productivity; value composition; and more. The industrial dimension can range from a narrow view of jobs in powertrain manufacturing to a comprehensive view including adjacent industries such as charging infrastructure. The common feature is that electrification and automation will result in job losses in the narrow automotive industry that encompasses battery manufacture. A study by CLEPA (2021) points to potential job losses in EU automotive manufacturing by 2040 of between 275 000 and 410 000. One compensating factor (within the industry) is the increasing value added from electronics and autonomous drive systems and the labour demand involved with setting up and maintaining the charging infrastructure. Another common feature of employment forecasts is that millions of jobs in the industry will be fundamentally transformed in terms of skills, place, contract type and working conditions. The only certainty is that all these changes will be on a massive scale: up to three million jobs will be fundamentally transformed in terms of skills and competences (BCG 2021).

Moreover, all the forecasts are based on the assumption of new car sales remaining stable, although this cannot be taken for granted. While fewer and fewer cars are being sold each year, stability in sales revenue has resulted from cars getting bigger and more expensive (see Pardi, this volume). It is also a standard assumption that changing mobility patterns would not have an effect on the number of cars as the current trend in electrification boils down to changing the engine without any rethinking of the concept of the car and, in broader terms, of mobility as such.

While most of the fears of industry actors, but also media attention, has been focused on the level of employment loss due to electrification, little attention has been paid to what would happen if Europe's car industry failed to keep pace with fast-evolving zero emission technologies. Certainly China, South Korea and many US companies are aiming to gain a competitive advantage in these technologies in the future. The greatest risk is missing the train, however. If European industry and policymakers were to slow down the mobility transition at this stage, it might undermine European competitiveness, creating the worst of all employment scenarios in the long term.

At this point, focusing on aggregate job gains or losses is therefore less important than developing solutions to help European companies, regions and workers master the transition. Even if the transition is managed in such a way that overall employment remains relatively constant, there will be stark impacts at plant level and at regional level.

The studies in this project reveal the depth of the changes taking place at national level as well as at that of the main manufacturers and suppliers in the context of fierce cost and technological competition.

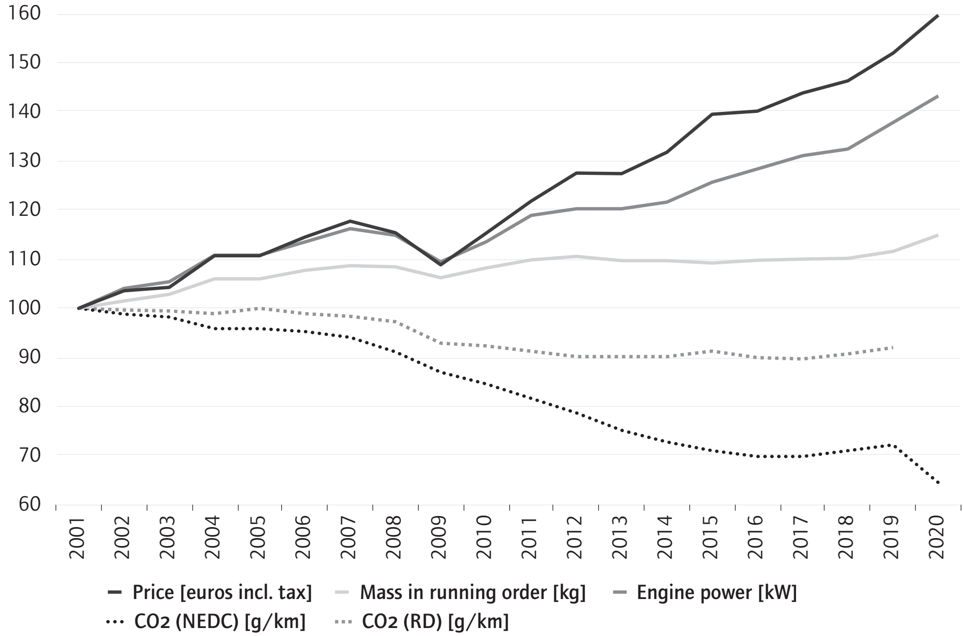
2. The unequal effects of the transition

The transition to electromobility is indeed gaining momentum and this is good news. In its current form, however, it is a very unequal process. Global investments in electromobility (electric vehicles and charging stations) have been picking up in the last couple of years. In 2021, global investment in the low carbon energy transition totalled 755 billion US dollars, up from 595 billion in 2020 (BNEF 2022). This figure includes investment in projects such as renewables, storage, charging infrastructure, hydrogen production, nuclear, recycling and carbon capture and storage (CCS) projects, as well as end user purchases of low carbon energy devices such as small-scale solar systems, heat pumps and zero emissions vehicles. Beside the welcome progress, what is striking in these figures is the shifting focus. As regards broad economic sector, the largest amount of investment in 2021 was still in renewable energy (366 billion US dollars) with an increase of 6.5 per cent over 2020. The most dramatic change, however, took place in the electrified transport sector, which showed a 77 per cent increase and came a close second to renewables with an investment of 273 billion US dollars (BNEF 2022). Before 2016, investments in the 'low carbon energy transition' were synonymous with investments in renewable energy generation and distribution, and electromobility had a negligible share; now, it is taking the lead. For the EU, investments in e-transport in 2021 were higher than investments in renewable energy systems, underlining the breakthrough developments taking place in electromobility.

This development also has important consequences for inequality. While the whole of society benefits from expanding renewable energy generation capacities, both in terms of CO_2 reduction and affordability, investments in electromobility – while certainly essential and beneficial for CO_2 reduction – benefit higher income persons and countries. This additionally reflects a regionally unbalanced development: 96 per cent of global e-transport investments (electric vehicles and charging stations) in 2021 were made in China, the EU and the US. Within the EU, the EU14 ('western Europe') accounted for 95 per cent while the 'new' Member States took just 5 per cent. The consequence is that new faultlines and new inequalities are emerging.

In part due to the EU regulation on car emission standards that allows higher CO_2 emissions for larger cars (weight-based CO_2 standards), new cars sold in Europe in the past decade have become heavier, more powerful and more expensive, as Figure 2 shows (see more in the chapter by Pardi, this volume).

Figure 2 **The average new car sold in Europe (price, mass, engine power and CO2 emissions), 2001-2020**



Source: Pardi (2022).

This upmarket drift has compromised the achievement of emissions targets (since much more effort is needed to achieve the same targets). In Real Drive circumstances, in the twenty years up to 2020 the average new car sold in the EU emitted 8 per cent less (under the New European Driving Cycle, this appears as a 36 per cent decrease), while engine power increased by 32 per cent and the price by 60 per cent. At the same time, as new cars and, in particular, electric cars have become less and less affordable, vehicle fleet change and thus the decarbonisation of individual transport becomes more difficult beyond the evident social justice concerns.

The chapters of this book analyse these challenges in great detail. Three studies deal with overarching issues: Tommaso Pardi provides a broad overview of the development of the EU regulatory framework, describing also the strategies and practices of the main manufacturers and featuring the regional characteristics of the industry across Europe; the study by Wolfgang Schade, Ines Haug and Daniel Berthold gives detailed analysis of Europe's emerging battery chains, a key factor for success in the mobility transition; and the chapter by Boy Lüthje confronts Europe with the challenge of China in the field of electromobility. Country studies follow on Germany, France, Czechia and Slovakia, Hungary, and Poland and Romania.

3. The main trends and characteristics of the European automotive industry and the challenge of China

The chapter by Tommaso Pardi considers the European automotive industry, focusing on the central role played by the European regulatory framework (on CO_2 emissions but also on vehicle type approval and on competition and trade policies within the Single Market). It shows how this regulatory framework has been shaping the industrial landscape over the last decades, as well as its responsibility for pushing the industry towards heavier, more powerful and more expensive cars (which the author calls regulatory upmarket drift) at a time when the imperative of reducing CO_2 emissions should have required lighter, less powerful and more affordable ones. He also demonstrates how this paradox lays at the origin of the Dieselgate scandal and is today one of the main factors explaining why only fast-track electrification can deliver the 2035 zero emissions target. The study also provides a comparative overview of the main manufacturers and regions in Europe, as regards the mostly generalist volume producers in France and Italy, the predominantly premium manufacturers in Germany and the integrated periphery in central and eastern Europe (CEE). Accordingly, while between 2000 and 2019 all major regions saw a decrease in the number of cars sold (from 9 per cent in Germany, 44 per cent in France and 51 per cent in Italy), employment in the industry grew only in Germany (by 3 per cent), falling by 43 per cent in France and 14 per cent in Italy.

Foreign direct investment has led to a spectacular expansion of the automotive industry in CEE countries, both in terms of output and employment. These are not high growth markets, but the competitive advantage of such production sites lies in them offering a cheap and flexible workforce to produce compact and small cars for the European and global markets. The author sees a rather uncertain future for them in the era of electromobility, although his main concern is how these countries could realistically board the Green Deal 'train' towards carbon neutrality in 2050 under the current conditions: they have the oldest, most polluting, rapidly ageing and fast-growing car fleets in Europe (mainly via second-hand car imports), while electric vehicles – in particular in association with the continuing upmarket drift – are not affordable for the majority of the population.

The chapter by Wolfgang Schade, Ines Haug and Daniel Berthold gives detailed analysis of Europe's emerging battery chains, providing an insight into how the EU is trying to catch up with Asia in the global battery race. The battery makes up a large share of value added for BEVs (36 per cent on average in 2020) and has a key role in stabilising employment; hence the authors' concerns.

In the first decade of automotive electrification, the development and scaling-up of battery cell manufacturing largely took place outside Europe. Now, at the beginning of the second decade, Europe is on the right path to developing its own 'local' battery cell manufacturing industry, having been successful in establishing a strong innovation network in all phases of battery manufacture, and is now catching up with the leading Asian manufacturers.

According to the authors, the EU is thus on a promising pathway towards building up capacity and competence, but risks remain. There are important decisions to be made about which battery chemistries to pursue. Current trends show European manufacturers moving towards upmarket segments while the lower price segment is being neglected. This might lead to a future equality issue, as well as to market vulnerability and a slower transition in lower-income countries. The critical raw materials are overwhelmingly being imported, creating supply chain risks, while efforts to develop domestic mineral resources in Europe are often met with local opposition.

The third cross-cutting chapter of this study, by Boy Lüthje, assesses what challenges China poses for Europe in the field of electromobility. China is now the global leader in the field, both in terms of production numbers and in the use of electric vehicles, as well as in qualitative factors such as charging infrastructure and mobility services; while it also leads in the production and development of electric batteries, including a strong sector in the mining and processing of raw materials. At the same time, China has become a key base for multinational carmakers from Europe, the US and east Asia seeking to develop mass BEV production and gain innovatory knowledge in the world's leading market. The author argues that China has not only become a global leader in electromobility, it is also challenging the established business model and questioning the position of the incumbents in global automotive value chains.

China certainly caught the opportunities of the impending disruptive transformation but it has also gained a leading position as first mover in BEV battery manufacture, a development based on a large pre-existing sector of battery suppliers for consumer electronics, computers and mobile phones. Within the automotive industry, Chinese battery producers are becoming important players as providers of core components, reaching out into other battery technologies such as fuel cells. The dominant strategy of Chinese firms, however, is reliant on specialised vertical integration across the industrial chain, including Li-ion battery cell production, raw materials mining and refining, cell materials and components, electronics assembly, packaging, the final assembly of electric cars and the building of charging stations. The major firms are expanding and integrating their activities into various stages of the production system, with vertical integration remaining the strategy around the specialised field of battery or electricity storage. This ongoing recombination is securing a dominant role for Chinese firms in global production networks both within the battery sector and within the production of electric cars in general.

In the field of labour relations, however, a particular challenge might be the emerging trend of the 'Foxconnisation' of automotive manufacturing in China under which contract manufacturers in electronics and battery manufacturing are becoming important players in BEV production networks.

4. Country specific trends

The chapter by Martin Krzywdzinski, Grzegorz Lechowski, Jonas Ferdinand and Daniel Schneiß argues that, despite its late start, Germany seems to be well equipped for the transition, with massive investments in electrification and a rapid expansion of battery manufacturing amidst a co-operative industrial relations culture. Still, even the headquarters of its flagship manufacturer, Volkswagen, is facing constant cost pressure and insecurity. A one hundred year old Daimler plant in Berlin, specialist in powerful combustion engines, has only just escaped closure by becoming the digitalisation centre of the group. There will be no employment loss, but job profiles will be radically transformed.

The authors add that the German automotive industry has been very successful with a product strategy focusing on the middle, upper and premium market segments while it has also been able to reconcile a high level of employment in Germany with the extensive use of low-wage locations in central eastern and south-eastern Europe. After sketching the strategies of the main manufacturers and suppliers towards electromobility, the authors point to the decisive effects of two consecutive crises, Dieselgate and Covid-19. Dieselgate shook the industry's faith in diesel technology and led it to withdraw support but the Covid-19 crisis created a window of opportunity, first because companies could now legitimise major restructuring plans and second because of the German government's massive EV subsidy programme.

The chapter by Sebastian Schulze-Marmeling on France delivers a contrasting picture, reporting a sharp fall in the market share of French manufacturers in the 2010s and severe employment loss, but with hopes of stabilisation through technological change and electrification that might also include the backshoring of some activities to France.

These two core countries, both Germany and France, are thus trying to keep as much competence as possible in the new technologies within their domestic locations.

In contrast, central eastern Europe, the main beneficiary of the post-enlargement expansion of the automotive industry, is now facing an uncertain future. The region is vulnerable and dependent on decisions made in headquarters locations. While some see potential in keeping combustion engine and hybrid technology alive for longer – thereby risking long-term competitiveness in return for short-term stability – others are embracing the transition to e-mobility by embarking on strong supplier positions, for example in battery manufacturing.

Petr Pavlínek, in his chapter on Czechia and Slovakia, delivers a detailed analysis of the development of the two countries towards electromobility with insights into the strategies of the main manufacturers and suppliers. Czechia presents a unique case with Škoda Auto, a tier two lead firm, being well positioned to transition successfully to the production of electric cars with a complete production cycle, including some R&D responsibilities and competencies not only for its factories in Czechia but for the VW Group as a whole. Even so, questions remain as to whether more competences and upgrading in internal combustion engine (ICE) technology can be seen as a buffer to ease the transition or whether this is instead a disadvantage to embracing fully electric vehicle manufacturing competences in the future. Meanwhile, Slovakia has seen a renewed expansion of foreign direct investment in the automotive industry, not least due to the latest investment by Volvo to establish an assembly site for electric cars. Both countries are, however, lagging behind Hungary and Poland in battery manufacturing capacities.

The chapter on Hungary by John Szabo, András Deák, Andrea Szalavetz and Gábor Túry also emphasises the dependent and vulnerable position of an automotive industry landscape dominated by foreign investment. There are four OEMs present – Opel, Suzuki, Audi and Daimler – soon to be joined by BMW, alongside an extensive supplier industry and a rapidly growing battery manufacturing base. To varying degrees all OEMs are embarked on the manufacture of electric vehicles while the swiftness of the expansion of battery manufacturing capabilities provides a good basis for securing a foothold in electromobility.

Philippe Darteyre and Stefan Guga, in their chapter on Poland and Romania, see several reasons why a smooth transition to electrified powertrains is bound to face significant headwinds in both countries, even if for different reasons. While the emerging battery competence in Poland might give OEMs an incentive and facilitate new job creation, the country's fossil fuel intensive energy mix significantly complicates the environmental equation. Romania, a country which is fiscally weak, could struggle to muster the necessary resources to invest in infrastructure, technology and market stimulus. The authors argue that powertrain electrification (in terms of both manufacturing and sales) is bound to be delayed in both countries. For vehicle manufacturing, this might be a delay of a few years but there is, nevertheless, much greater uncertainty regarding the large supplier industry in both countries. In Poland, combustion engine manufacturing is currently highly developed and is one of the country's major export industries; while in Romania the manufacture of ICE transmissions and components has soared over the past decade. Furthermore, there is little indication of any investments in Romania seeking to replace activities that are bound to disappear as electrification progresses, although the picture in Poland is more positive because of the country's important investments in battery manufacturing capabilities.

5. Key findings

– The EU regulatory framework on car emissions has followed a bumpy road in the last 30 years. Climate and environmental targets have been inconsistent, testing procedures have malfunctioned and weight-based CO_2 emissions standards have operated in favour of heavy and powerful cars, compromising a large part of the emissions reductions which have been achieved.

- Continuing upmarket drift in the electric vehicle era not only raises questions about social justice but, by slowing down fleet change, is also putting the achievement of climate objectives at risk.
- Not least since the announcement of the European Green Deal, the transition to e-mobility has become inevitable due to both policy and technology cost reductions but also to market developments.
- In the new geopolitical constellation, after Russia invaded Ukraine, this has grown even clearer. Climate, pollution, energy security and industrial competitiveness are now fully aligned. The phasing-out of ICE for new car sales is sealed, but the period over which fleet change will take place is uncertain.
- After a late start, the EU is well placed in this rapid technology race, including also in vertical integration encompassing the battery value chain. It must continue to have urgent regard to this race if it is to protect domestic automotive industry jobs; the alternative – not competing – is far worse.
- Despite the EU being well placed, economic geography risks are mounting – competition from both China and the US is increasing and the accessibility of key raw materials is a strategic weakness for Europe.
- Regional disparities might grow and will need policy attention (core-periphery; original equipment manufacturers-suppliers).
- While electrification results in employment loss in the narrow automotive manufacturing industry, a slower transition, which has often been seen as smoothing out the transition risk, is actually the biggest risk and could potentially lead to bigger losses in both competence and jobs in the future.
- The employment effects due to deep structural change will be enormous: none of the 14 million jobs in the broad industry will remain unaffected. Millions of jobs will disappear, while others are being created albeit with completely new job profiles and skills requirements. Further employment risks may appear if European manufacturers continue to abandon the lower market segments of electric vehicles and to leave these to foreign competitors.

6. Conclusions

Europe has embarked on fast-track electrification and manufacturers are committed to delivering the now official target of zero emission new cars and vans by 2035. The process is, however, far from optimal and the design of the EU regulatory framework has certainly played a role.

The weight-based emissions standard and the incentives provided for PHEVs are driving upmarket drift in which cars are becoming bigger, heavier, more powerful and more expensive. Higher prices, in turn, are reducing affordability and creating new inequalities.

Despite all this damage caused in the past decade, the CO_2 regulation's weight adjustment formula is losing significance with maturing electrification and with further regulatory updates. From 2025, two changes will come in with regards to how the weight adjustment is calculated. First, following the move to the Worldwide

Harmonised Light-Duty Vehicles Test Procedure (that is, a test which is closer to real world emission figures), the reference mass will be updated every two years (instead of three years before 2025). This is expected to reduce the weakening impact of the weight adjustment on carmakers' CO_2 targets.

However, the trend of upmarket drift and the move towards SUVs, that has certainly been boosted by the weight adjustment principle, is not only about CO_2 emissions. Weight-based emissions standards were, and are, dysfunctional in many ways. To start with, they make cars structurally more emissions intensive; hence carmakers need to make more efforts to reach those targets. Being less affordable, divisions between regions, but also within individual countries, are deepening while the lack of affordability also means fewer low emission new vehicles in circulation and more old ICEVs left on the roads. And, while upmarket drift has further accelerated with electrification, it means not only a higher carbon footprint for heavier batteries but also a higher level of extraction of minerals (and a higher raw materials footprint).

The second regulatory update comes in the area of batteries. In respect of battery development there is a vicious circle: the heavier the car, the heavier (and more expensive) the battery. Here, might EU battery regulation be a way to limit upmarket drift? The new EU battery regulation will set carbon footprint reporting, calculated as the kg of CO_2 equivalent to each kWh of the energy provided by the battery over its expected service life. This means that producers will be incentivised to make batteries with cleaner and more efficient processes but which are not necessarily smaller. To incentivise the production of smaller batteries, one would need a carbon footprint limit per battery or a corporate fleet average limit.

One reason for upmarket drift is that carmakers have prioritised a high end, low volume strategy to maximise profits. SUVs in Europe, on average, sell for almost 60 per cent more than an equivalent car and manufacturers appear to be culling small cars in the pursuit of profit. VW, Stellantis and BMW have all announced that they are moving towards selling fewer cars and focusing on more premium, high-end models. This ongoing drift is undermining the broader shifts in mobility, especially given low investment in public transport and in integrated transport solutions. There is, consequently, a danger of movement towards a mobility that is class-based.

Second-hand car markets need further regulation. It is not sustainable for polluting second-hand cars to end up in the poorer Member States of the EU. Corporate fleets can certainly play a role and CO_2 standards for fleet mandates – together with the existing Clean Vehicle Directive – may help to develop second-hand EV markets. However, vehicle fleet change cannot only be based on corporate fleets in the expectation of second-hand EVs trickling down to serve private markets in the poorer countries.

Europe also needs smaller, affordable, entry-level electric cars. While carmakers can make more profit on every SUV sold, the small car segment is where the volume is. If European carmakers give up this segment, models by BYD, Great Wall Motor and SAIC's MG will take their place. Most of the revenue from the small cars sold in Europe will then be generated in China. A failure of EU carmakers to scale up BEV supply could thus result in foreign carmakers offering affordable models and capturing a large share of the mass market in Europe. And, with the mass market comes mass employment. If the EU is unable to regulate its own market efficiently, it risks losing economic sovereignty in the automotive industry.

While there is justified criticism of the current regulatory framework, the necessity of electrification is not being questioned. Electrification is inevitable and is itself an important pillar for achieving clean mobility objectives. However, the current path of upmarket drift, based on universal car concepts, does not properly fit into a new sustainable concept of mobility. Such a mobility concept assumes a new role for individual transport within mixed modes of transport. Electrification combined with upmarket drift not only collides with the principles of just transition but also weakens its potential. At the same time, neither does it fit into a sustainable mobility paradigm shift. Even if public transport provisions were to be developed on a massive scale, the trend could result in a class-based mobility system (and, in any case, investments in public transport and integrated mobility services are lagging behind).

There are important challenges to be overcome before this transition can be considered a success. Rolling out a sufficient charging infrastructure across Europe will require determination and close attention must be paid to affordability, both for low-income households and for low-income regions.

7. Policy recommendations

The weight-based formula in CO_2 standards for cars and vans needs to be phased out by the time of the 2026 review of the emissions regulatory framework. Furthermore, fuel efficiency criteria and material demand criteria for meeting transport needs must to be introduced as part of the revised regulatory framework.

EU battery regulation should be strengthened. The new EU battery regulation (from 2027) aims to set a reporting framework based on the carbon footprint of the battery. To incentivise the production of smaller batteries, an absolute carbon footprint limit per battery, or a corporate fleet average limit, would be necessary. Overall efficiency and battery sizing should be addressed via dedicated European rules and national tax systems.

Existing regulation should be refined by the adoption of systemic thinking which takes into account transport infrastructure, smart cities, trade policy and material flows and which considers life cycle emissions criteria.

Public transport and mobility services should be developed – infrastructure development is over-focused on individual mobility.

The second-hand car trade needs to be re-regulated via stricter recycling criteria for polluting cars (and which does not question Single Market rules).

Regulators should ensure European small cars do not disappear. Incentives for building small electric vehicles should be provided based on industrial policy initiatives, local content provisions and public procurement rules. Subsidies for electric cars should support entry-level models 'made in Europe'.

Coalitions must be built which highlight the dysfunctionality of the current regulatory framework. In particular, consumer organisations should be encouraged to demonstrate that consumer demand for smaller affordable electric cars does exist, while the viability of the universal car concept as the basis for electromobility also needs to be challenged (i.e. just switching out the engine without developing a new concept for mobility).

Just transition policies will be needed to help this massive restructuring process. The rationale that the Just Transition Fund is meant for carbon intensive sectors and regions, and that this is not the case for this industry, cannot be taken seriously. The industry is undergoing unprecedented restructuring not because the production process itself is carbon intensive but that this is the result of consumers' use of the product. The Just Transition Fund needs to be expanded and equipped with more resources to deal with the inclusion of the automotive industry and automotive-heavy regions, while a just transition framework tailored to the needs of the industry needs to be set up.

Social and employment policies should create an enabling policy environment for managing employment transitions, skills development and job displacements. While most competence for these is concentrated at EU Member State level, guidance should be provided at European level.

Electricity grids and clean electricity should be developed and upgraded to meet the demands of vehicle electrification and be made ready for smart charging solutions.

Electricity markets need new regulation to make sure that electricity market prices are not linked to fossil fuel energy prices.

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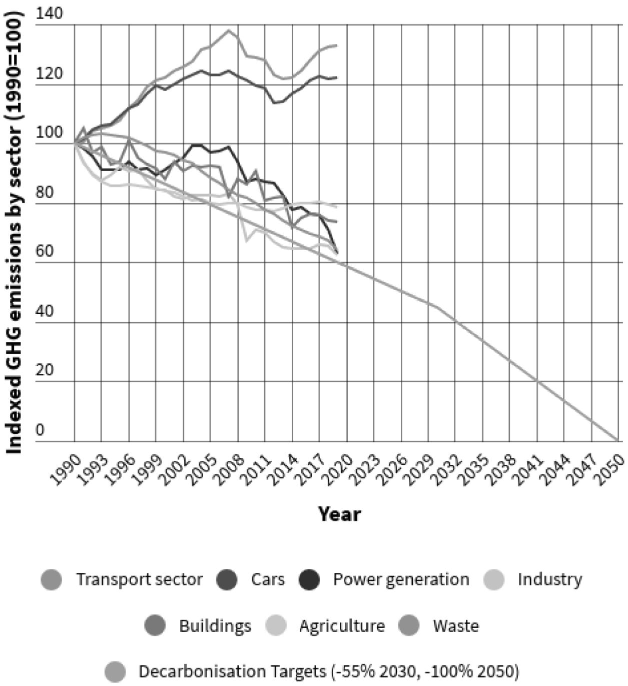
Chapter 1
A European perspective of a fast-track transition to electromobility

Tommaso Pardi

Introduction

Between 1990 and 2019, the European transport sector was expected to reduce its CO_2 emissions by 40 per cent to keep track with the 100 per cent CO_2 reduction target on the 1990 level set by the European Commission for 2050. But, in fact, the transport sector has increased its CO_2 emissions by 32 per cent during these last 30 years, with passenger cars representing 43 per cent of total CO_2 emissions from the transport sector (see Figure 1).

Figure 1 **Greenhouse gas emissions by sector, 1990-2020**



Source: T&E 2022.

This growing divergence between the historical trajectory of CO_2 emissions of passenger cars in Europe and where they were supposed to go to reach carbon neutrality in 2050 is the main reason why the European automotive industry is now facing the most radical and potentially disruptive transformation of its history. Rapid and widespread electrification appears today as the only possible technological solution to reconcile this diverging path with the EU Green Deal. In the EU Green Deal the short-term objective is to reach, by 2030, a 55 per cent reduction in CO_2 emissions (on 1990) in all economic sectors – the 'Fit for 55' package. For passenger cars the proposal made by the European Commission in 2021 foresees not only a 55 per cent reduction of the CO_2 emissions of new cars by 2030 but a 100 per cent reduction by 2035. In other words, in slightly more than ten years, the internal combustion powertrain that has been at the core of this industry for more than a century, and which concentrates around 25 per cent of the value added and 40 per cent of the total employment of the European automotive industry, will be phased out.

Most of the current debate, reports and publications about this fast-track electrification of the European automotive industry concentrates on its potential positive and/or negative effects – on national economies, on vehicle manufacturers and suppliers, on employment and on CO_2 emissions (Verhaeghe 2021; Falck et al. 2021; T&E 2021; Strategy& 2021; BCG 2021) – while less attention is being paid to the role of the regulatory framework.

This chapter focuses on the central role played by the European regulatory framework (on CO_2 emissions but also on vehicle type approval and on competition and trade policies within the Single Market) in shaping the industrial landscape as well as its responsibility for pushing the industry towards heavier, more powerful and more expensive cars (what we call regulatory upmarket drift) precisely at a time when the imperative of reducing CO_2 emissions should have required lighter, less powerful and more affordable cars. We show how this paradox was at the origin of the Dieselgate scandal and is today one of the main causes of the accelerated process of electrification.

We also highlight the contradictions that arise by combining this pre-existing upmarket drift with accelerated electrification. The result is quicker upmarket drift that significantly reduces the environmental benefits of electrification while making its economic, social and political costs much higher.

The chapter is organised in six sections.

Section 1 provides a historical review of different environmental regulations and policies and their contradictions, highlighting also strong path dependencies. It reconstructs the political struggle that occurred in the 1990s between premium and generalist brands in Europe to define the emergent European regulatory framework for the Single Market and for its greening trajectory. We look at the elaboration of technical and environmental standards but also at the definition of the trade and competition rules of the Single Market and at the (increasingly subordinated) place of industrial policy.

Section 2 focuses on the making of the EU regulatory framework to reduce CO_2 emissions for cars and vans in the 1990s and 2000s.

Section 3 analyses the consequences of this EU regulatory framework on the supply of new cars in the Single Market. We will see in detail how this regulation resulted in cars that are structurally more, rather than less, polluting.

Section 4 analyses the consequence of the Dieselgate scandal both on the European regulation of CO_2 emissions, which has become stricter, and on upmarket drift which has increased during this period, driven by the need to electrify very heavy and powerful cars, making these cars even heavier, more powerful and more expensive.

Section 5 delves into the consequences of combining regulatory upmarket drift with the electrification that has accelerated it, looking into the environmental, economic, social and political consequences of such a process. We see that heavier electric vehicles (EVs) are structurally much less green than lighter EVs and that weight and engine power are even more important for EV performance (driving range and recharging time) and production costs (size and weight of the battery and of the vehicle) than for equivalent internal combustion engine (ICE) vehicles.

The sixth and last section analyses the 'Fit for 55' proposal made in 2021 by the European Commission to increase the CO_2 reduction target for new cars in 2030 from 37.5 per cent to 55 per cent and to introduce a 100 per cent reduction target for 2035. We discuss the implications of such a hardening of the target in terms of upmarket drift and its foreseeable impact on work, employment and consumers.

In the conclusion, we summarise our findings by stressing how much the combination of regulatory upmarket drift with accelerated electrification can be disruptive and unsustainable for the European automotive industry, for the EU Green Deal and for the green transition. But we also argue that combining electrification with regulatory downmarket drift could open up much more sustainable scenarios for the future of the industry and for the capacity of the European Union to achieve carbon neutrality in 2050.

1. Historical background: air quality or fuel economy?

Historically, the European Union lagged behind in the introduction of environmental standards and regulations for the transport sector. The United States started to regulate the air pollutants emitted by cars in 1966 with the Clean Air Act. In 1970, the US Congress passed an amendment to the Act that called for 90 per cent reductions of hydrocarbons and carbon monoxide emissions to be achieved by 1975. Before the end of the decade, unleaded petrol and the three-way catalytic converter, required to achieve these drastic reductions in air pollutants, were made mandatory by US standards. It had been the European premium car manufacturers that had first developed these technologies for the US market (Bergquist and Näsman 2021), but it took more than a decade before similar environmental standards were introduced in the European market. Furthermore, even when the Euro norm for air pollutants was finally made into European law in 1991, it still lagged behind US standards by several years, in particular concerning diesel engine emissions.

There are several reasons for this delayed introduction of environmental standards in Europe. The first difficulty concerns the interplay between national and European standards. The second difficulty was posed by the costs of adopting US environmental standards in Europe, as the cost of catalytic converters represented on average 5 per cent of the total cost of a premium model but between 15 and 22 per cent of the total cost of a small/compact car (Moguen-Toursel 2004).

Another reason was that, at a time when the reduction of fuel consumption had become a national and European priority after the two oil shocks of 1973 and 1981, introducing a technology that would increase fuel consumption by 5-15 per cent appeared problematic.

The trade-off between stricter air pollutant standards and higher fuel consumption is of the greatest importance in understanding the almost opposite historical patterns taken by the environmental regulation of car emissions in the United States (for a description of the US regulation, see the longer version of this chapter on the ETUI website) and in Europe.

1.1 Europe: fuel economy and diesels

While the US maintained strict air pollution standards and paid less attention to fuel economy (and CO_2 emissions), in Europe the historical configuration was almost reversed. Here, the focus since the 1970s has been on fuel consumption regulated at national level with high petrol prices and fiscal policies that have favoured low consumption cars for economic rather than environmental reasons. The 1980s were characterised by the increasing market penetration of small and compact cars that contributed to reducing average fuel consumption as well as the average real price, weight and size of European cars (Freyssenet et al. 1998; Loubet 2001; Moguen-Toursel 2004). The introduction of US standards for air pollutants was expected to raise the acquisition and ownership costs of these entry-level market cars as well as national fuel consumption and oil imports. The focus on fuel economy also concerned German premium car manufacturers that, during this period, significantly increased the share of diesels in their sales – from 13 per cent to 23 per cent between 1980 and 1985 – mainly to professionals, in particular taxi drivers and sales representatives who were demanding more fuel efficient large cars.

As a result of this trend that favoured fuel consumption over air quality, when the Euro norm for air pollutants was finally introduced in 1992 it was much less demanding than the equivalent US standard. The Euro norm was not calculated on average fleet sales, as was the case for the US standard, but only as a series of limit values for air pollutants per vehicle category that were, on average, 30-40 per cent weaker than those set by the US standard. Also, starting with the Euro 2 norm, introduced in 1996, diesel engines benefited in Europe from weaker limits for NOx than petrol engines, while this was not the case in the US (Blumberg and Posada 2015). Finally, US standards were regulated by the EPA that carried out random tests each year on 15 per cent of the models on sale to check if their emissions corresponded to those certified by their car manufacturers, while the Euro norm was managed by the European Commission Directorate General (DG) in charge of Enterprise and Industry (not by the DG in charge of Environment). Furthermore, its application was delegated to Member States with no ex post verification by any autonomous European authority. While weaker environmental regulation benefited the generalist manufacturers, it also opened the way towards more diesel.

As we will see later, this weaker regulatory infrastructure created loopholes that could be exploited by car manufacturers to manipulate test results without any real control by a European-wide regulator. In terms of trajectory, it also opened up the possibility to make more systematic usage of diesel engines when the European Union increased its requirements in terms of fuel economy.

In the 1990s, diesel engines were no longer confined to large cars for professional use: they became the main technological solution to meet the voluntary CO_2 target in 2008 (set at 140g CO_2/km), agreed by the European Automobile Manufacturers' Association (ACEA) in 1998, and then the mandatory EU targets of 2015 (set at 130g CO_2/km for average new car sales). When Dieselgate erupted in 2015, diesel models represented more than half of the total sales of European new cars and more than 40 per cent of the total fleet.

Because of this historical interplay between different environmental standards and company strategies, Europe was on a unique trajectory in comparison with any other major market for cars. In the US and China, diesel cars were almost non-existent, with market shares below 2 per cent.

1.2 Premium vs. generalist: the political struggle over the Single Market rules in the 1990s

In the previous section we saw how both the European and the US markets for new cars were characterised by specific trajectories in terms of product mix and technological choices. In both cases, our analysis shows that the role of consumer preference, often evoked to justify these divergent trends, and the inherent transformations of markets towards larger and more powerful/polluting cars was much less important than generally assumed. In the US case, when stricter Corporate Average Fuel Economy targets and high petrol prices became the norm in the 1970s, consumers rapidly shifted their preference towards smaller and fuel efficient compact cars whose market penetration could only be stopped by freezing the market shares of Japanese car manufacturers over four years (between 1981 and 1985).

We propose to introduce the notion of 'conception of control' to characterise what happens and what is at stake in this type of regulatory struggle. We then use this notion to understand the genealogy of the European regulatory framework for new cars that emerged with the creation of the Single Market in 1992 and the institutional causes of both Dieselgate and of the current accelerated transition towards electrification.

The idea of 'conception of control' was developed by the economic sociologist Neil Fligstein (Fligstein 2001; Fligstein and McAdam 2012; Fligstein 1990). It refers to the cultural framing of how companies are supposed to behave and compete in any given market so that competition does not disrupt the market structure but rather reproduces it. Conceptions of control are historically defined by the dominant actors in a given market and are reflected in its institutions and therefore also in its environmental regulation. Once established, conceptions of control are resilient but can occasionally be destabilised in times of crisis. During these historical conjunctions, 'challengers' – smaller firms with different types of products or services, foreign competitors and 'invaders' from other sectors – may try to establish a different conception of control in the market. When this happens, political struggle follows over the definition of the regulatory framework. 'Incumbents' try to re-establish the status quo via government intervention; while 'challengers' try to institutionalise new conceptions of control. Once these struggles are resolved either way, a new phase of stability follows, characterised again by strong institutional and cultural path-dependency.

In the case of the 1970s crisis in the US, the 'challengers' were the Japanese car manufacturers that sold compact cars whose price, quality and fuel economy could not be matched by US car manufacturers. The political response was to re-establish the status quo by creating the light trucks protected market and bringing back fuel prices to pre-crisis levels. Eventually, the Japanese 'challengers' dropped their alternative conception of control in the 1980s when they started to produce larger cars and light trucks in North America.

In Europe the structuring of a conception of control was more complex because, before the creation of the Single Market from 1992, two different conceptions of control co-existed in the Common Market and had been institutionalised in different national markets (Jullien et al. 2014). The battle over environmental standards for air pollutants illustrates the two blocs that challenged each other and their respective conceptions of control.

On the one hand, there were the producers of large and luxury cars in Sweden, but mainly in Germany, that were pushing for the highest technological solution – the three-way catalytic converter and the use of unleaded petrol. On the other hand, there were the producers of small and compact cars from Italy and France that were looking for alternative low cost solutions – improving fuel quality, using lead traps, developing cleaner compact engines and also introducing a European harmonised speed limit to reduce air pollution (Moguen-Toursel 2006, 2004).

1.3 From the Common Market to the Single Market

With the creation of the Single Market, Europe had to choose between the two conceptions of control and decide how to regulate the market for new cars in each and all Member States. These political decisions (and struggles) concerned the harmonisation of technical regulations, including environmental standards, and the definition of supranational trade policies and competition rules.

1.3.1 Technical standards: towards an international upmarket harmonisation

Before the creation of the Single Market, French and Italian generalist car manufacturers managed to contain the pressure towards higher technical standards (in line with US standards) exerted mainly by German car manufacturers (Ramirez Pérez 2010). Their arguments in favour of affordability both in terms of acquisition cost and usage cost (fuel economy) carried weight not only within their own governments but also at European level (Jullien et al. 2014). In addition, the absence of EU type approval for motor vehicles meant that each Member State retained a form of national control over technical regulations. With the creation of the Single Market, the need to harmonise European technical regulations towards unique standards and avoid any disruption of the free circulation of goods meant that the coexistence of the two conceptions of control became problematic. The introduction of the Euro norm in 1992 marked a victory for the premium conception of control. It also established a cultural hegemony of premium car manufacturers over European technical and environmental regulations as tools for promoting and diffusing technological innovation (Moguen-Toursel 2004; Ramirez Pérez 2010; Bergquist and Näsman 2021).

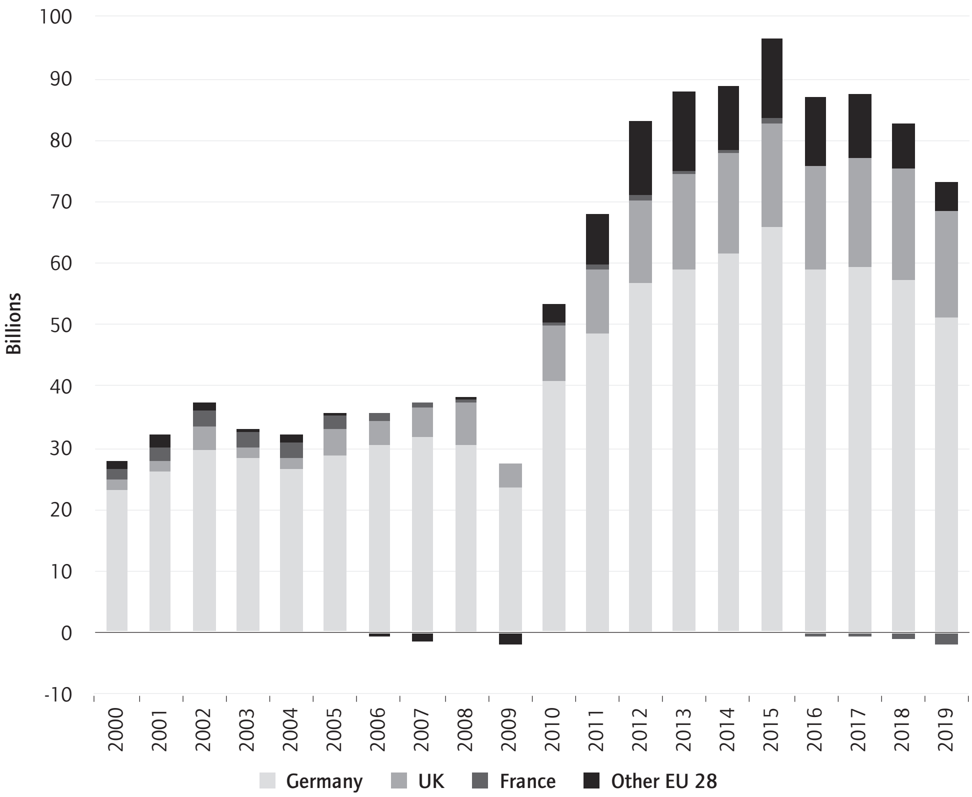
1.3.2 Trade policies: from the European fortress to free trade

Premium car manufacturers had relatively small shares of their domestic markets (due to the high price of their models) and were therefore historically dependent on exports to achieve economies of scale. Generalist car manufacturers had large market shares in their domestic markets (over 70 per cent in the case of France and Italy) and their priority was to protect these markets against direct price competition from foreign importers. The process of European integration represented a middle ground between these two conceptions of control. The Common Market had provided premium car manufacturers with more opportunities for exporting their high margin cars than for generalist car manufacturers but it still protected the domestic market shares of the latter (Jullien et al. 2014; Pardi 2010).

When in 1989 the European Commission started to negotiate the conditions of access to the Single Market for Japanese car manufacturers, a fierce struggle began between the partisans of the two conceptions of control (Jullien et al. 2014; Seidenfuss and Kathawala 2005)subsequently covering a 1991 VER between the European Union (EU. French and Italian car manufacturers wanted to preserve the European fortress – they were acting as 'incumbents' pleading for the reestablishment of the status quo. What they wanted was to establish a renewable quota that would freeze imports and regulate or even prevent Japanese direct investment in Europe. The German car manufacturers, but also a majority of European countries, including now the UK, were only ready to accept a temporary EU quota on Japanese sales. Such a quota was meant to give the European automotive industry time to modernise and become more competitive without compromising the expected benefits of the Single Market to spur competition and increase efficiency in the industry (Jullien et al. 2014). Eventually, after two years of intense negotiations, a quota on Japanese sales was negotiated, fixing at 16 per cent of the Single Market the maximum market penetration of Japanese brands in 1999 from a starting point of 11 per cent in 1992 (Gandillot 1992).

The temporary and exceptional character of the Japanese quota also meant that EU trade policies were now evolving towards greater trade liberalisation and less protection. As we will see later, after the expiry of the quota the European Commission began to negotiate a fast-increasing number of free trade agreements in the 2000s and 2010s, including with countries such as Mexico, Korea and Japan that were amongst the main global exporters of motor vehicles and auto parts. These policies have been generally considered a success in the automotive industry as the EU trade surplus in motor vehicles significantly increased from an average of around 30 billion euros in the 2000s to more than 80 billion dollars in the 2010s. Yet, almost the entirety of this surplus came from Germany and was made by premium car manufacturers (72 per cent of the EU28 total and 95 per cent without the UK in 2020) while generalist car manufacturers in France and Italy rather suffered from these measures: not only did they eventually run trade deficits with non-European countries in automotive vehicles (see Figure 2 below) but also the sale of foreign brands in Europe steadily increased from 16 per cent in 2000 to 25 per cent of the EU market in 2020.

Figure 2 **Extra EU28 trade balance in motor vehicles, 2000-2019, in billions of euros**



Source: Eurostat.

1.3.3 Competition policy and industrial policy

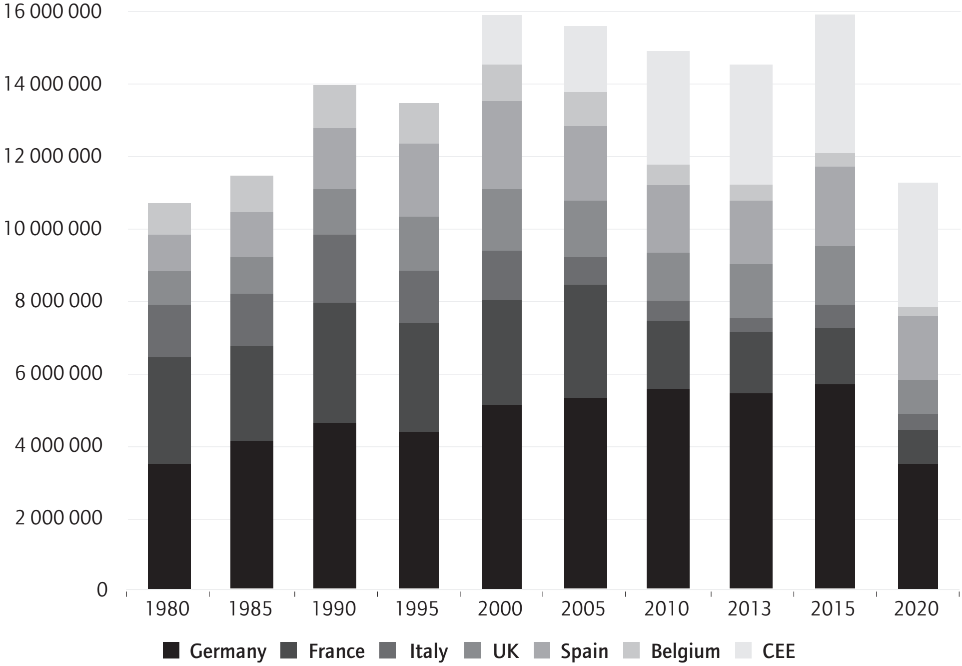
A third key contested ground between the generalist and premium conceptions of control in Europe was the articulation between competition policy and industrial policy. The competition policy of the European Union was historically shaped by German ordo-liberalism and promoted as such by DG Competition (Warlouzet 2008). Ordo-liberalism confers a strong role on the state in order to guarantee market competition, but the state should only act as arbiter and not intervene in the economy to develop or protect any industrial sector. Industrial policy, in contrast, pushes the state to intervene in the economy for either social reasons (protection of employment, development of lagging regions) or strategic ones (supporting and developing key economic sectors).

In the 1970s and 1980s, in a context of economic crisis marked by the two oil shocks, generalist car manufacturers in France, Italy and also the UK were greatly reliant on industrial policies that supported their national champions via state aid, recurring currency devaluations and different kinds of protectionist measures including nationalisations when key companies like British Leyland or Renault had almost gone bankrupt. But with the signature of the Single European Act in 1986 the pressure from Germany and other northern European countries, now including the UK under Margaret Thatcher, to reinforce supranational competition policy and limit the level of state intervention in southern economies increased. The push for stronger European competition policies occurred in an ideological context marked by the diffusion of neoliberal ideas that wanted to limit the role of the state and let the economy be driven only by the free market (Warlouzet 2008). Eventually, the Maastricht Treaty of 1992 placed the Single Market under the control of DG Competition and drastically reduced the scope of vertical industrial policies (and the influence of DG Enterprise and Industry) (McGowan 2007; Kassim 1996): it banned direct state aid to individual companies; it limited annual state deficits to 3 per cent of GDP; and it set the stage for the introduction of the Euro currency in 1999 that would take away the exchange rate as a tool to restore cost competitiveness in manufacturing.

As we can see in Figure 3, the relative national shares of the EU production of passenger cars remained fairly stable through the 1980s and 1990s despite several crises and increasing import penetration.

With the new institutional order established by the Single Market, premium car manufacturers gained market shares (increasing by 48 per cent between 2001 and 2020) and increased production in their host countries, particularly in Germany as well as in central and east European countries where new capacities were installed during this period. On the other hand, the market shares of generalist car manufacturers came under strong pressure (declining by 37 per cent between 2001 and 2020) and production collapsed in their host countries (Jullien et al. 2014; Pardi 2017).

Figure 3 **European production of passenger cars by country, 1980-2020**



Source: CCFA, ACEA, OICA.

The Single Market and its new institutional order offered generalist car manufacturers new opportunities to compensate for their declining market shares and margins. These consisted in reducing production costs, labour costs in particular, by relocating manufacturing to the low wage Member States of central and eastern Europe, integrated in the European Union since 2004, and to ultra low wage countries (such as Morocco, Algeria, Turkey or Ukraine) integrated in the EU customs union during the same period (Pavlínek et al. 2017; Jullien and Pardi 2013).

Premium car manufacturers also reduced production costs in their domestic bases by shifting the manufacture of lower value added sub-assembly parts to these countries (Fana and Villani 2022).

These massive processes of relocation in both automotive assembly and sub-assembly have structured a European regional value chain in which the new Member States have been integrated as low wage and low value added assemblers and suppliers for western and global transnational original equipment manufacturers (OEMs) (Pavlínek 2020; Pavlínek et al. 2017).

The comparison with the integration of Spain and Portugal in 1986 can be useful here to highlight what changed between these two periods of European enlargement.

1.3.4 European enlargement: from market seeking to efficiency seeking

Spain and Portugal were both low wage countries with an early specialisation in automotive manufacturing and could have been used by transnational car manufacturers to relocate production and drive down labour costs in Europe. But this did not happen. In the fifteen years following their integration in 1986, vehicle production doubled in Spain and Portugal while the sale of new cars tripled, contributing to the overall growth of European vehicle production and sales during this period (see Figure 3 above). Wages also significantly increased during this period and caught up with those of the Italian automotive industry.

In contrast, while central and east European countries also benefited from access to the Single Market via structural funds and FDI, they were not able to retain vertical industrial and trade policies to protect and develop their domestic industries and markets.

Without the possibility of deploying sectoral industrial policies, their economies became completely dependent on the investments and strategic decisions made by foreign transnational companies: the average rate of foreign ownership of automotive industries in central and east European countries is well above 90 per cent against 80 per cent for Spain and Portugal and between 10 per cent and 20 per cent for France, Italy and Germany (Pavlínek 2022, 2018).

Low production costs became a condition for keeping FDI flowing. Moreover, industrial relations systems could not be institutionalised at national level: collective bargaining takes place at company level with very weak and scattered union representation (Drahokoupil and Myant 2016; Beblavy et al. 2011). As shown by Fana and Villanni (2022), between 2005 and 2015 the share of profit in the value added imported by western European automotive industries from central and east European countries increased significantly: in France, for instance, the share of imported profit in total profit rose from 34.3 per cent to 52.5 per cent. Much of the productivity gains generated by FDI and the modernisation of production in central and east European countries in the 2000s and 2010s were not distributed to workers.

Finally, the early attempts by central and east European governments to protect and develop their domestic markets for new cars were systematically shut down by the European Commission (DG Trade and DG Competition) and by the European Court of Justice (Pardi 2018).

As a result of this neoliberal form of European enlargement (Drahokoupil and Horn 2008), in the fifteen years following the integration of central and east European countries, the production of new cars in these countries exploded as a result of massive FDI, growing by 160 per cent; while the sale of new cars increased by only 30 per cent from post-Soviet levels.

2. From the Single Market to the Dieselgate scandal: the role of CO_2 emissions regulation in the 2000s

At the beginning of the 2000s the premium ordo-liberal conception of control was almost fully endorsed by the European Commission. When in 2006 the Commissioner for Enterprise and Industry, Günter Verheugen, addressed the European Parliament on the topic of the restructuring of EU industry, his speech 'Competitiveness – the answer to restructuring and competition' sounded like an ordo-liberal manifesto, emphasising the need for a strong industry in Europe, but no longer supporting 'non competitive' European national champions. [1]

The European Commission also created in 1995 a 'high-level' group called CARS 21 whose purpose was to provide the technical groups and committees of the Commission with a consensual view of the regulations that would 'boost the competitiveness of the European automotive industry' (Klüver 2013). The CARS 21 report, published in 2012, endorsed the upmarket drift of European cars as the only solution to the crisis in the industry. It advocated the German model based on premium cars, high technology and exports to emerging countries for the whole of Europe.[2] The influence of German automotive manufacturers over the shaping of EU regulations for the industry during this period and beyond has been well established in the literature (Klüver 2013; Gössling et al. 2016; Haas and Sander 2019; Batho 2016; Katzemich 2018; Nowack and Sternkopf 2015).

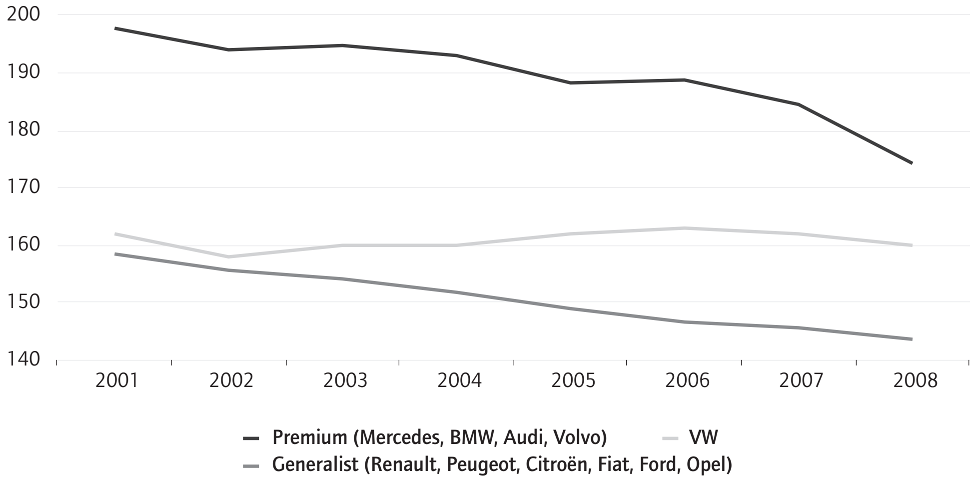
However, if the premium German manufacturers clearly emerged from the 1990s as the 'incumbents' with strong cultural and political influence over EU regulators, they were also confronted with a significant disruptive threat to this new institutional order. The ACEA had agreed in 1998 to a voluntary CO_2 target of 140g CO_2/km for 2008 and of 120g CO_2/km for 2012. But by 2005 it had become clear that the European car manufacturers would not reach the target. The issue concerned almost exclusively the German premium car manufacturers and Volvo.

2.1 The emerging structural contradiction between premium cars and CO_2 emissions reduction

As we can see in Figure 4 below, generalist car manufacturers made the required efforts to reduce their CO_2 emissions and were on their way to achieving the voluntary target of 140g/km. By 2008, Fiat, Citroën, Peugeot and Renault had succeeded in bringing their average CO_2 emissions to or below 140g/km; Opel (149g/km) and Ford (151g/km) had failed, but by a much smaller margin than VW (160g/km) and the premium brands (174g/km).

1. Debate in the European Parliament on the restructuring of EU industry, Brussels, 4 July 2006, quoted by Houben (2016: 228).
2. See also: https://gerpisa.org/node/1526.

Figure 4 **Average CO2 emissions (g/km) of new cars sold by groups of European brands, 2001-2008**



Source: EAE, ICCT.

On 7 February 2007, the European Commission published the results of the review of the CO_2 reduction strategy. The Commission found that the agreed, but voluntary, target of 120g CO_2/km 'will not be achievable by 2012' (European Commission 2007: 7). The new proposal consisted of making the 120g CO_2/km reduction target binding by 2012. This represented a major threat to premium car manufacturers.

Ten years earlier, when the targets had been negotiated, German manufacturers tried to have the target expressed in terms relative to existing emissions (a 25 per cent reduction) whereas French companies agreed that the voluntary target should be expressed in grammes per kilometre (Wagner 2009: 277).

As we have seen before, the producers of heavier and more expensive premium cars had a clear advantage when it came to reducing air pollutants. The expensive technology they had pioneered for both petrol and diesel engines – the catalytic converter – consisted in filtering the pollutants so that their actual volume was not a factor. In contrast, the volume of CO_2 depends on the amount of fuel consumed: heavier and more powerful cars, which structurally consume more fuel, also emit more CO_2.

The reason why premium brands had failed to reach the 2008 voluntary target was quite straightforward: their average car sold in 2008 weighed 1622 kg, 100 kg more than in 1998 and 328 kg more than the average car sold by generalist brands. Even if they sold more diesel models (69 per cent of their sales) than generalist brands (53 per cent) this was not enough to compensate for the extra weight and engine power. On average, a 10 per cent increase in weight leads to a 7 per cent increase in fuel consumption (IEA 2019). Furthermore, heavier cars need more powerful engines that also lead to higher fuel consumption: on average, a 10 per cent increase in engine power leads to a 5 per cent increase in fuel consumption (ICCT 2017; Tietge et al. 2019).

This trend highlights a fundamental contradiction between, on the one hand, upmarket drift – towards more expensive, more sophisticated, more powerful and heavier cars – and, on the other, the institutionalisation of a regulatory-driven reduction of CO_2 emissions by the European Commission to fight global warming and climate change from 1998.

As we have started to see, in Europe the delayed introduction of stricter air pollutant standards allowed for the diffusion of a different technological solution: the diesel engine. Diesels were perfectly coherent with the premium conception of control because they improved the fuel economy of large cars. Nevertheless, they presented two major problems, in particular if they had to diffuse to the other segments of the market:

1. Their 27-37 per cent fuel economy over equivalent petrol engines (IEA 2019: 46) came at the price of ten-twenty times more NOx emissions and, while catalytic converters had temporary solved the issue for the first lax Euro norms (1 and 2), it was clear that, with the expected evolution of these towards stricter standards (see Figure 7), it would become much more difficult and expensive to homologate diesel cars, in particular in the lower-medium segments;
2. Diesel engines were more complex and expensive than petrol engines so that diesel models cost on average between 9 per cent and 21 per cent more than equivalent petrol models (IEA 2019); being more expensive, they also tended to be heavier and more powerful, offsetting most of their fuel economy (T&E 2017).

The dieselisation of European sales thus implied a trade-off between CO_2 reduction and air pollution that was not compatible with the evolution of Euro norms towards stricter standards (it would eventually result in real emissions of NOx being, on average, five times higher than the Euro 6 limit – see Figure 7 below). At the same time, dieselisation did not resolve the contradiction between the premium conception of control and the reduction of CO_2 emissions as it pushed the European supply of new cars further upmarket.

2.2 The French-German political struggle over weight-based standards

The creation of the high-level CARS 21 group in 2005 was meant to build consensus inside the ACEA and the Commission on new regulatory standards, in particular on new environmental standards compatible with the premium conception of control. The group notably argued for the introduction of weight-based CO_2 targets. These targets would still be expressed in grammes per kilometre, as proposed by the Commission, but with adjustments in respect of the average weight of the cars sold by each brand. French and Italian manufacturers were not ready to make concessions on this as weight-based targets meant that the producers of lighter cars would have more demanding CO_2 targets than the producers of heavier ones. An intense political battle followed with the Verband der Deutschen Automobilindustrie (VDA; a trade coalition), Volkswagen and the German government progressively bypassing the ACEA, which had been paralysed by the conflict (Beez and Richter 2011: 161; Scharte 2010: 140), and directly lobbying the Commission to shift its position on CO_2 emissions targets towards the German premium conception of control.

Klüver (2013) analysed the lobbying activity that followed the publication of the initial proposal by the Commission in February 2007 and its effects on the final draft of December 2007. It showed that the most influential actor during this first phase was the VDA, whose demands were largely integrated by the Commission in the final draft of the regulation: the CO_2 target was weakened from 120 to 130g CO_2/km; weight-based targets with a 60 per cent slope were introduced;[3] and vans were separated from cars with milder CO_2 targets, again to compensate for their extra weight.

The VDA did not succeed in delaying the application of the regulation that was still meant to apply from 2012 onwards.

It did, however, win on two main issues. In exchange for keeping the 60 per cent slope, the full implementation of the 130g CO_2/km limit was postponed to 2015; and eco-innovations would now count up to an extra CO_2 reduction of seven grammes, almost exclusively available to German premium car manufacturers. Also, the amount of the penalty was significantly reduced for the first three grammes beyond the target, providing further flexibility for premium car manufacturers. With the only exception of the longer-term target of 95g CO_2/km for 2020 being maintained, Regulation 443/2009 of 23 April 2009 'bore an unmistakeably German hallmark' (Haas and Sander 2019: 18).

As highlighted by the environmental NGOs involved in the negotiation, the introduction of weight-based CO_2 targets had crucial implications for the whole European automotive industry:

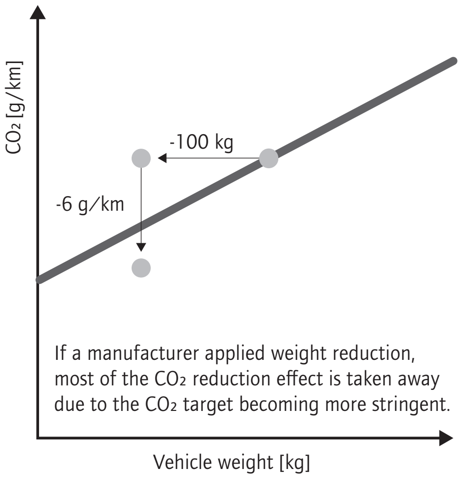
> Weight-based CO_2 standards for cars are a very bad idea for the following reason: they punish positive action. Carmakers who reduce their vehicles' weight (one of the most important paths to cutting CO_2 emissions) would be faced with a stricter CO_2 standard. Therefore, they do not help to break the trend towards ever-heavier vehicles, which is one of the major reasons why car CO_2 emissions have not come down quickly enough in recent years. (T&E 2007)

Premium car manufacturers had thus obtained a CO_2 regulation that not only did not penalise the upmarket drift towards heavier and more powerful cars but which also penalised those car manufacturers that did not follow it (see Figure 5).[4] Regulation was therefore now pushing the entire industry in the exact opposite direction of what should have been the logical approach to increasing fuel economy: reducing the mass and the engine power of new cars (IEA 2019; Serrenho et al. 2017; ICCT 2017; T&E 2007).

3. VDA asked for an 80 per cent slope while French car manufacturers tried to negotiate one of 30 per cent (Nowack and Sternkopf 2015).

4. 'The Regulation does include a modality to ensure that any overall increase in the weight of all vehicles sold does not weaken the overall target. However, this is done by lowering the targets of all companies uniformly, so that the penalty of increasing mass is shared across all carmakers, whether or not they sell heavier cars.' (T&E 2007: 23).

Figure 5 **The weight-based target system**



Source: ICCT.

Upmarket drift, which was in clear contradiction to the 2008 CO_2 voluntary target, was now institutionalised as the only way of achieving the CO_2 binding targets for 2015 and 2020. Only more diesels, more direct injection petrol and more 'eco-innovations' could deliver the expected CO_2 reductions. However, all these expensive technologies contributed to increasing the price, weight and power of cars. It was an impossible equation. The contradiction that already existed between the premium conception of control and the reduction of CO_2 emissions was now enforced via the EU regulation on generalist car manufacturers as well, putting the whole European automotive industry against the wall of the Dieselgate scandal.

3. Regulatory upmarket drift: the 'wrong way' to reduce CO_2 emissions

Upmarket drift can be seen as the consequence of the growing regulatory pressure towards the most advanced and demanding technical and technological standards concerning safety, quality and pollution. This was historically advocated by premium German car manufacturers to harmonise EU standards with US ones and it has been progressively institutionalised at EU level since the creation of the Single Market.

The Institutionalisation of this increasing regulatory pressure was coherent with the ordo-liberal regulation of two other key policy domains that shifted from national control to EU control since the Maastricht Treaty of 1992: trade policy, which favoured the export of high value added products; and competition policy, which provided the tools for reducing the production costs of these products inside the EU.

Upmarket drift has already been identified as one of the causes of Dieselgate (T&E 2017). But it has been mainly attributed to a combination of corporate greed – pushing higher value added products to increase margins and profits even though these cars were structurally higher polluting – and consumer preference for larger and more powerful cars (T&E 2018: 32).

When we look at car manufacturers, going upmarket is a natural strategy for premium brands, because they extract value from selling more expensive cars to wealthy consumers, but not for the generalist brands that have historically controlled the European market. These brands were successful in going downmarket by selling larger volumes of smaller, lighter, cheaper cars such as the Fiat Panda, the Renault Twingo, the Peugeot 205, the Opel Corsa and the Ford Fiesta on which the profitability of these car manufacturers depended in the 1980s and 1990s (Freyssenet et al. 1998; Loubet 2001; Volpato 2009; Tolliday 2003).

If generalist car manufacturers started to make heavier, bigger and more expensive versions of these models in the 2000s, it was because they had now to comply with a premium regulatory framework, notably reinforced by the 2009 regulation on CO_2. That they did so out of necessity rather than choice can be deduced in that the more they went upmarket, the more their sales declined (see Figure 11 below). By going upmarket, generalist brands were not only moving away from their customer base but they were also trying to squeeze expensive premium technologies into lower margin cars. They struggled to make profits and relocated most of their production to low wage countries inside and outside the EU to reduce costs (Jullien et al. 2014; Pardi 2017, 2019).

Yet, almost all the generalist carmakers went through major crises during this period and have had to be rescued by their governments and/or merged with other carmakers to survive. Opel, Fiat and PSA merged under the control of PSA to create Stellantis in 2021; while Renault obtained a loan of 5 billion euros from the French state to survive the Covid-19 crisis but announced cuts of 15 000 jobs in 2020.

In contrast, during this same period, premium car manufacturers regularly increased their market shares and preserved profitability and employment.

When we look at consumers, we see that what changed with upmarket drift was not consumer preference but consumer composition. As the average European car became more expensive, sales shifted towards the wealthier northern European countries where consumers tend to buy larger and more powerful cars than consumers in southern European countries. Also, inside each national market, sales shifted towards wealthier and older households that tend to buy more premium large cars. Finally, households in general have seen their capacity to buy new cars in Europe decline, with most sales shifting towards company cars where, once again, premium models tend to be overrepresented because of their higher residual values.

3.1 The average European car between 2001 and 2020: heavier, more powerful, more expensive and more polluting than before

Figure 6 below shows the evolution of the main characteristics (mass in running order, engine power and CO_2 emissions in the homologation test and on the road) of the average car sold in the Single Market between 2001 and 2020.

Upmarket drift was initially linked with the dieselisation of sales that equally concerned all brands (see Figure 12 below). As diesel market share increased, from 36 per cent in 2001 to 53 per cent in 2007, mass increased by 9 per cent (110 kg) and engine power by 16 per cent (12 kW). As a result of this trend, the fuel economy generated by dieselisation was completely offset by the extra weight and power. While the tested CO_2 emissions (on the basis of the New European Driving Cycle (NEDC)) slowly diminished during this period in a late attempt to meet the 2008 voluntary target (a reduction of 6 per cent), this was due almost exclusively to test-oriented optimisation practices,[5] while Real Drive CO_2 emissions decreased by only 2 per cent. The optimisation of tests is measured by consumer associations that collect data on real fuel consumption from private owners of cars (a detailed presentation of this data is available in Tietge et al. 2019). According to these sources, during this period the optimisation rate doubled from 8 per cent to 16 per cent, mainly driven by premium brands and diesel models (Tietge et al. 2019).

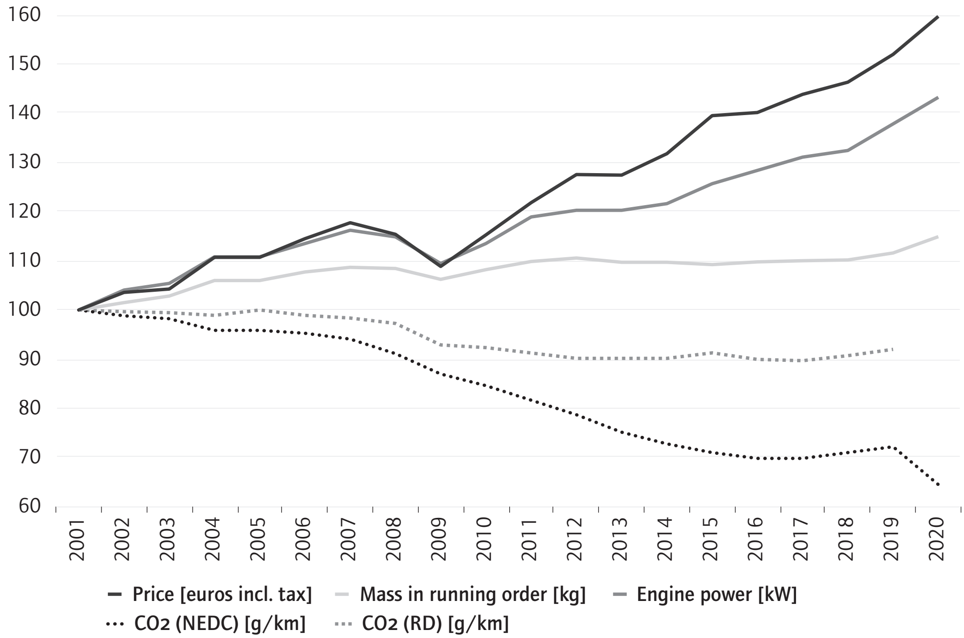
The impact of the 2008-09 financial crisis temporarily reversed upmarket drift. Thanks to the generous scrappage schemes made available in all major European markets to sustain demand, and thanks also to the introduction of environmental bonuses for lower consumption cars, middle class owners of old second-hand cars were given the opportunity to buy (again) new cars. They massively opted for cars that were cheaper, lighter and less powerful than the average, and which were mostly petrol, pushing downmarket the average car sold in 2009: in one year, it became 1300 euros cheaper (6 per cent) and emitted 8g CO_2/km less (according to Real Drive data) than in 2008.

The exceptional situation of 2009 shows how virtuous a downmarket drift of the European sales of new cars can be for environmental and social reasons. It also shows that upmarket drift had not been due to consumer preference but to consumer composition.

After the establishment of binding CO_2 targets in 2009 for 2015, even with the advantage of weight-based targets that were coherent with the premium conception of control, premium car manufacturers still had to reduce their emissions significantly (from 168g/km to 138g/km – a drop of 17 per cent). But they could rely on further dieselisation (from 70 per cent of sales to 78 per cent) and the rapid increase in the share of direct injection petrol models (from 43 per cent to 92 per cent).[6]

5. Test-oriented optimisation builds on exploiting the 'flexibilities' permitted by the NEDC in order to obtain favourable test results (for example short test cycles, non-realistic vehicle preconditioning (Tietge et al. 2019)).
6. Direct injection petrol can reduce the CO_2 emissions of petrol powertrains by up to 14 per cent.

Figure 6 **The average new car sold in Europe (price, mass, engine power and CO_2 emissions), 2001-2020**



Source: EEA, ICCT, author's calculations.

For generalist car manufacturers the task was somehow less demanding (from 140g/km to 122g/km – a drop of 13 per cent) but it was much more difficult for them to expand dieselisation in a context of crisis (their share of diesel models actually declined from 53 per cent to 49 per cent) also due to the introduction of the Euro 5 norm in 2009 and Euro 6 in 2015. These lowered the emissions limits for NOx g/km, significantly increasing the relative cost of homologating diesel models in the lower segments.

As a result of these different strategies, after again increasing rapidly between 2009 and 2012, the mass of the average European car stabilised at around 1400 kg before starting to rise again at the end of the decade. Nevertheless, upmarket drift did not otherwise stop: the average European car became longer (10 cm), wider (4 cm) and taller (2 cm) between 2008 and 2019, and also much more expensive (from 23 147 euros to 30 485; a rise of 32 per cent); the share in total sales of automatic transmission and four-wheel drive vehicles, which also add weight and CO_2 emissions, rose from 13 to 41 per cent and from 9 to 15 per cent respectively during this period; and engine power increased by a further 20 per cent.

As in the previous period, the net result of this contradictory trend was an increasing difficulty in achieving the anticipated CO_2 reductions. As remarked by Skeete (2017: 379), 'it would appear that part of OEMs' difficulty in hitting emissions targets is self-inflicted'. But this time the industry did not have the luxury of failure due to the binding nature of the targets. The industry's answer consisted of using new technologies further to optimise fuel consumption and CO_2 emissions in the homologation test in order progressively to meet the 2015 average target of 130g CO_2/km.

As we can see in Figure 6 above, the optimisation rate of homologation tests (NEDC) by comparison with real drive conditions (RD), which had already doubled between 2001 and 2008 from 8 to 16 per cent, reached 40 per cent by 2015. This accelerated progression was the result of the diffusion of optimising technologies and techniques from premium to generalist car manufacturers via the introduction of new models (T&E 2018; Tietge et al. 2019). In general the optimisation rate remained much more important for the heavier cars of premium brands (46 per cent) and for diesel models (41 per cent) than for the lighter cars of generalist brands (37 per cent) and for gasoline models (35 per cent) (Tietge et al. 2019: 8-13, 33).

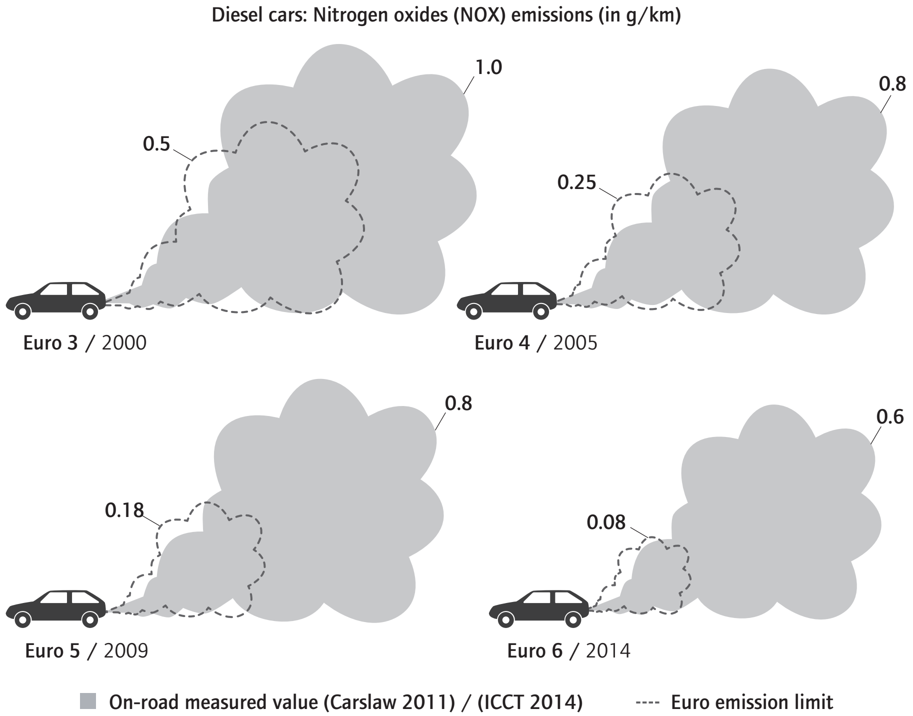
The fast increase of optimisation in this period was not the result of a progressive fine-tuning of the test procedure by the car manufacturers, as in the previous period, but the consequence of the deliberate introduction of new models equipped with 'cheating' devices capable of manipulating the test results. For instance, the average optimisation rate of CO_2 emissions of the VW Passat, one of the highest selling models in Europe, passed from 5 per cent to 33 per cent in just two years after the introduction of a new model in 2009 (Blumberg and Posada 2015: 22).

Generalist car manufacturers were not less 'guilty' than premium car manufacturers; they simply needed to optimise the tests less because their cars were structurally less polluting. In contrast, when it came to optimising the homologation tests for NOx to make their cheaper diesel models compliant with the Euro 5 and Euro 6 norms, they could not 'afford' the more sophisticated after-treatment technology used by premium brands (Klebaner 2019). Consequently they did not hesitate to optimise the tests, by more than 500 per cent on average and by up to 1200 per cent for the cheapest diesels available from Renault, Dacia and Fiat, versus 200-500 per cent for the German premium brands.

While there is no moral justification for the behaviour of the European automotive industry (including the foreign brands operating in Europe), it is also important to stress how this reprehensible outcome was the logical consequence of the institutionalisation by the European Union of upmarket drift.

Between 2001 and 2015, the average European car gained 10 per cent of mass and 26 per cent of engine power which was structurally equivalent to an increase of 21 per cent of CO_2 emissions. During the same period, the industry was supposed to reduce CO_2 emissions by 20 per cent, from 169g/km to 135g/km (NEDC). This extra 21 per cent of emissions generated by upmarket drift meant that what was really demanded was a reduction of 41 per cent. Such a reduction would not have been possible even if the entire fleet of new cars had been made up of diesel models by 2015. Eventually, the net result was a reduction of 30 per cent in CO_2 emissions: two-thirds of the reduction compensated for upmarket drift and the rest accounted for the 9 per cent effective CO_2 reduction (RD). Unfortunately, this was less than half of what European car manufacturers were supposed to achieve.

Figure 7 **Optimisation rate of NOx emissions in Euro 3, 4, 5 and 6 for average European diesel cars, 2000-2014**



Source: ICCT (Blumberg and Posada 2015: 20).

The Dieselgate scandal would probably have erupted sooner or later, since these optimisation rates were already in the public domain in Brussels amongst experts, lobbyists and regulators (Blumberg and Posada 2015). But the Commission was, at the time, relegating the debate on the introduction of more realistic homologation tests to relatively obscure technical committees where the question could have hung on for several years before some compromise was found (Batho and Rohfritsch 2016). Yet, the trigger for the scandal came from the US.

Starting from 2009, Volkswagen successfully homologated in the US some of the same diesel vehicles that barely conformed in Europe to the Euro 5 norm. Yet, the US standards were twice as stringent. How this was possible was one of the questions that started the enquiry by ICCT in 2013 that established that this was indeed not possible and that, on average, these vehicles emitted between 10 and 20 times more NOx in RD conditions than those allowed by the US regulation (Baldino et al. 2017). The European Commission could no longer turn a blind eye to the growing optimisation rates and the whole industry was now ‘in the dock’.

3.2 Dieselgate and its regulatory outcomes: stricter but not different

The Dieselgate scandal had two major consequences for the European automotive industry on its way towards the 2020-21 target of 95g/km of CO_2 set by the 2009 regulation. The first was the hardening of the regulation with the introduction of a new, more realistic homologation test in 2017, the Worldwide Harmonised Light Vehicles Test Procedure (WLTP), coupled with a Real Drive emission test meant to cut optimisation rates below 10 per cent; and the introduction of more severe penalties in cases of non-compliance – 95 euros for each gramme beyond the limit multiplied by the total number of cars sold. The second was the complete disqualification of the main technology developed and promoted since the 1990s to achieve CO_2 reductions: diesel. Starting from 2016, diesel sales plunged and, by 2019, had fallen below 30 per cent (from 52 per cent in 2015).

Under these conditions, it was clear that the only way the European industry could achieve the 95g/km of CO_2 average target in 2020 (on 95 per cent of sales) and in 2021 (on 100 per cent of sales) was by substantially increasing the sales of electric vehicles (battery electric vehicles (BEVs); and plug-in hybrid electric vehicles (PHEVs)). Not only would sales of BEVs and PHEVs substantially reduce average CO_2 emissions, since BEVs qualified as zero emission vehicles and PHEVs as around 40g CO_2/km ones, but they would also benefit from the super-credits introduced in 2013 for the sale of cars emitting less than 50g/km of CO_2 (zero and low emission vehicles (ZLEVs)). These counted double in 2020; as 1.66 vehicles in 2021; and as 1.33 vehicles in 2022 (with an overall cap for the three years of 7.5 g/km per car manufacturer).

Until this moment, sales of BEVs and PHEVs in Europe had been marginal: 1.4 per cent in 2017 and 2 per cent in 2018. The question was now which market share of EVs would be required to pass the cap in 2020 and 2021; and whether it would undermine the premium conception of control destabilised by Dieselgate.

The battle that started in 2017 over the new EU regulation on CO_2 emissions for cars and vans showed that premium manufacturers were still trying by all means to defend the status quo and keep the market share of EVs as low as possible. The proposal made public by the European Commission in November 2017 'had the VDA's influence written all over it' (Haas and Sander 2019: 19). The new targets for 2025 and 2030 were still expressed in percentages, meaning that the weight-based targets would be preserved. Additionally, the targets were in line with the historical gradual decline of emissions, with a 15 per cent reduction for 2025 and a 30 per cent reduction for 2030 (T&E, the main environmental NGO, had been asking for a 60 per cent reduction). Finally, no compulsory quota for EV sales was demanded, only voluntary quotas of 15 per cent ZLEVs for 2025 and of 30 per cent for 2030, both associated with policy incentives but no penalties for the car manufactures that failed to achieve them.

This time, however, the Commission faced significant opposition from the European Parliament: a coalition of 19 EU Member States led by France, Italy and Spain pushed for more stringent targets for CO_2 reduction (20 per cent in 2025 and 40 per cent in 2030) and higher quotas of ZLEVs (20 per cent in 2025 and 35 per cent in 2030) associated with severe financial penalties. Once this counter-proposal had been officially backed by the European Parliament, both the VDA and the ACEA announced that 'it could spell the end of the European automotive industry' (Haas and Sander 2019: 20).

Despite being pushed by southern European countries, generalist car manufacturers did not act as 'challengers' and rather followed the VDA in its attempt to preserve the status quo. It is also interesting to note that even the environmental NGOs which had denounced the weight-based targets back in 2008 were now ready to accept them if the industry was ready to go electric in exchange. For instance, in its submission to the Commission, T&E declared its position on the 'utility parameter' (which refers to the weight-based standards) as 'neutral'. ICCT, the US NGO, also suggested keeping the utility parameter but asked for it to be changed from a mass parameter to a footprint one in line with the US standards for CO_2.[7]

After an intense struggle and marathon negotiations between the Commission, the Parliament and the Council, the final result was a mild compromise that hardened the terms of the Commission proposal for 2030 (a 37.5 per cent reduction target rather than 30 per cent; and a 35 per cent ZLEV quota rather than 30 per cent). Nevertheless, the 'spirit' of the proposal was, given the circumstances, left intact (Haas and Sander 2019: 21-22): the weight-based targets and premium eco-innovations were preserved; no change was made to the weight-based slope to allow for weight reductions; and no penalties were to be associated with missing the ZLEV quotas for 2025 and 2030.

4. From diesels to electric vehicles: towards accelerated upmarket drift

In this section we break down the data on new cars sold between 2001 and 2020 by two groups of brands: the premium group (German Mercedes, BMW and Audi (Volkswagen group), plus the Swedish Volvo), whose average car price in 2001 was €32 900; and the generalist group (French Renault, Peugeot and Citroën, Italian Fiat, US-German Ford Europe and Opel (plus Vauxhall in the UK)), whose average car price in 2001 was half of the premium price at €16 500. We consider Volkswagen separately for three reasons: it is a hybrid brand that shares platforms with a premium one (Audi); it has a price position closer to the generalist group, but substantially higher (€20 500 in 2001); and it is a brand which has gone strongly upmarket during the period studied.

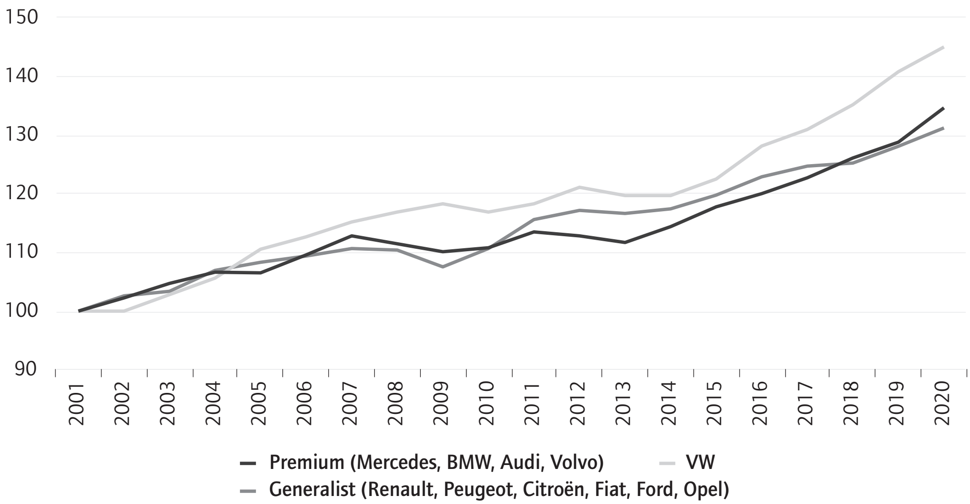
We analyse first the impact on premium and generalist brands of the upmarket drift generated by the dieselisation of the 2000s and 2010s before shifting our attention to the recent electrification of new car sales in 2019 and 2020.

7. The advantage of a footprint utility parameter is that it does not penalise weight reduction, although it is structurally unfavourable to producers of micro and small cars.

4.1 The divergent impact of dieselisation on premium and generalist brands

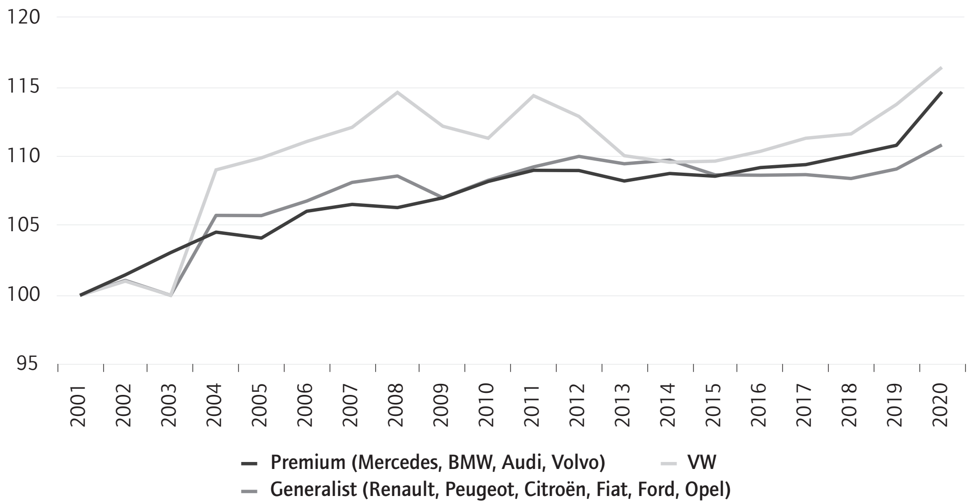
The first purpose of this analysis is to show that the generalist group has indeed played the upmarket game, following the premium group upmarket and increasing the weight and engine power of its average car sold in the European market in a similar proportion to the premium group. We can also see that, during this period, Volkswagen has gone more upmarket than the European average both in terms of weight and engine power.

Figure 8 **Average engine power (kW) of new cars by brands, 2001-2020**



Source: EEA, ICCT, author's calculations.

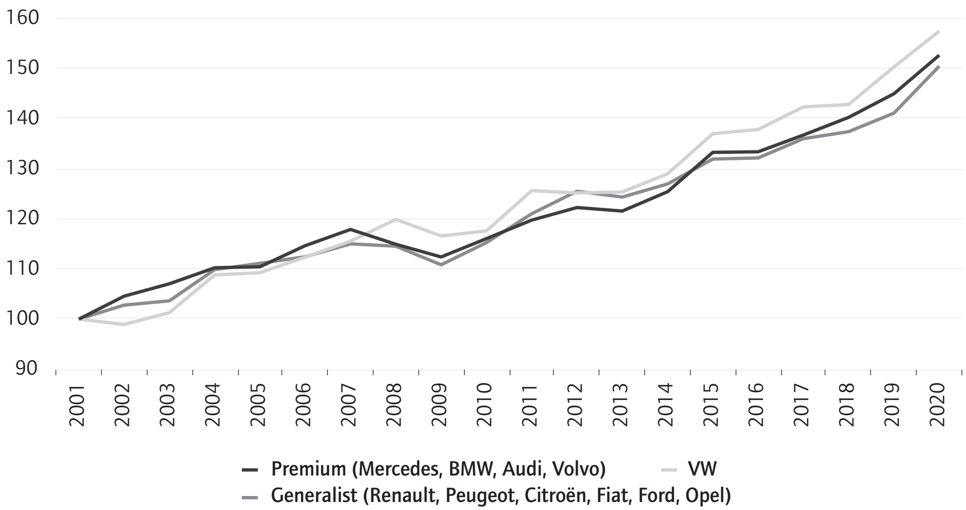
Figure 9 **Average mass in running order (kg) of new cars by brands, 2001-2020**



Source: EEA, ICCT, author's calculations.

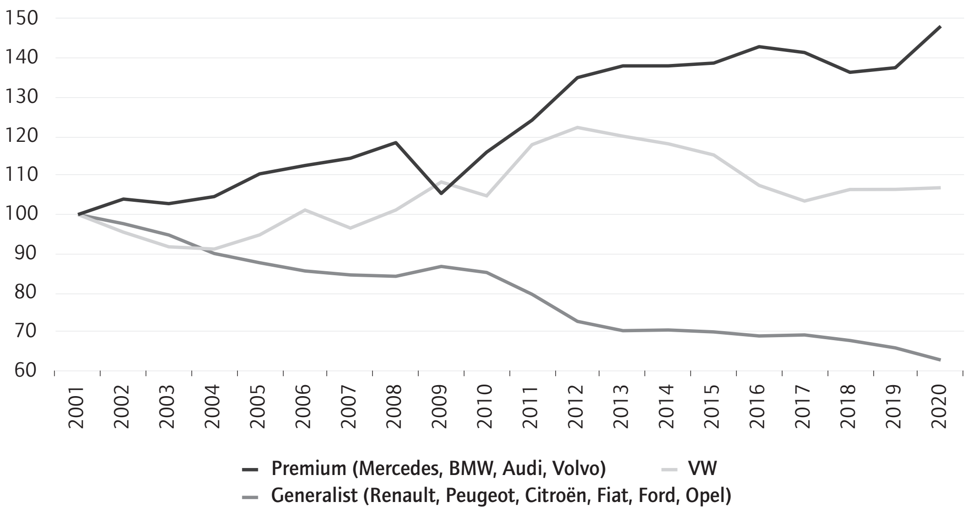
As a result of this common trend towards heavier and more powerful cars, the prices of the average cars sold by the two groups have also grown in similar proportion (see Figure 10 below). Prices grew by 50-53 per cent between 2001 and 2020 (and by almost 60 per cent for VW) when, during the same period, EU28 inflation (via the consumer price index) grew by 38 per cent. As we have mentioned before, and as we will see in more detail later, cars have become substantially more expensive during this period and much less accessible to the average European household.

Figure 10 **Average price (€) of new cars by brands, 2001-2020**



Source: EEA, ICCT, author's calculations.

Figure 11 **Sales of new cars (volume) by brand, 2001-2020**



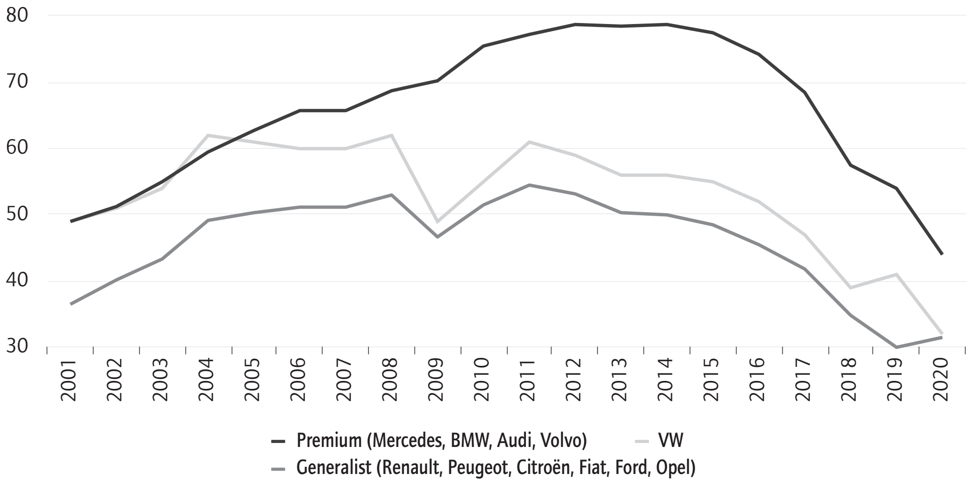
Source: EEA, ICCT, author's calculations.

Upmarket drift has also significantly distorted competition between the two groups. The premium group's market share almost systematically increased as prices grew faster than average inflation, and only decreased when prices dropped in 2009 or in the aftermath of Dieselgate (see Figure 11). In total, the sales of the premium group grew by 48 per cent between 2001 and 2020. The Volkswagen brand also substantially gained market share across most of the period (an increase of 15 per cent between 2001 and 2015) and, despite the impact of Dieselgate, its market share was still 7 per cent higher in 2020 than in 2001. In contrast, the generalist group's market share plunged during the same period by 37 per cent.

Why did the generalist group play this losing game? The answer is that it did not have the choice. The upmarket regulatory pressure described above prevented generalist car manufacturers from going downmarket to meet CO_2 targets and to protect their market shares by making more affordable cars. The Dacia brand of the Renault Group, developed and produced in Romania, the lowest wage country in the EU, and more recently in Morocco, can be seen here as an exception in that it successfully gained market share at the bottom of the market. However, Dacia was actually the brand that went most upmarket during this period precisely to comply with the EU regulatory framework (see Text Box 1).

Under the conditions set by the premium conception of control, only expensive technologies such as diesel engines and direct injection petrol could deliver to the generalist brands the CO_2 reductions required by the regulation. But squeezing these premium technologies into generalist small and compact cars was extremely difficult, requiring them to be made heavier, more powerful and more expensive. The transformation of these cars into SUVs was the strategic answer of generalist car manufacturers to deal with upmarket drift. Nevertheless, it reinforced upmarket drift and further shifted demand towards premium brands.

Figure 12 **Average diesel share of new cars by brand (%)**



Source: EEA, ICCT, author's calculations.

The Dacia brand: the exception that proves the rule

Dacia can be seen as the exception to the general decline of the generalist brands. Its market share increased almost continuously between 2004 (0.4 per cent of the EU28 market) and 2020 when it reached 3.4 per cent. When Renault took control of Dacia in 1999, the project was to develop a low cost brand for emerging central and east European markets. The Logan, to date the only low cost model below 7000 euros manufactured in Europe, was launched five years later on the Romanian market at a price of 5000 euros.

Romania was then not yet part of the European Union and it was not affected by the import of foreign used cars that were flooding the Polish market. Romania's integration into the EU in 2007, however, threatened to reproduce the Polish scenario. The Romanian government reacted by introducing a 'first registration tax' of around 140 euros for a new car and up to 8000 euros for an imported one, depending on its age. The Commission launched an infringement procedure in November 2007 on the grounds of violation of Article 90 of the EU Treaty. The Romanian government gave in, aligning the first registration tax for imported used cars with that for new cars. The consequence was a collapse of new car sales that, in 2019, were still 48 per cent below the 2007 peak (Jullien et al. 2012: 25).

Dacia survived the collapse of the Romanian market by shifting its market focus from east to west. The success of the Logan in western markets was initially a surprise, even for Renault. The buyers of the Logan came from among owners of very old cars who had been off manufacturers' marketing radar for years. Later, however, the new models in the Dacia range – the Sandero and the Duster compact SUV – targeted these markets more explicitly. At the time of its launch in western Europe, the Logan was sold at a base price of 6000 euros and the Duster was sold at an average price of 15 000 euros with some versions exceeding 20 000 euros. In 2016, a quarter of Dacia's European sales were made in France and a little over three-quarters in western European countries, confirming a de facto substitution of low-end Renault brand sales by low-cost Dacia brand models.

Because of this shift from east to west, and from low wage to high wage markets, the upmarket drift of the Dacia brand was the most pronounced amongst all brands. Between 2005 and 2011, the average Dacia sold in Europe gained 19 per cent in mass (198 kg) and 87 per cent in price (6177 euros). This upmarket drift was not only about making the Dacia brand more appealing to western European consumers, it was also the simple result of making the Logan, and then the rest of the Dacia entry range, compatible with European technical norms, at the same time further contributing to the collapse of potential markets for new cars in Romania and in other central and east European countries (Pardi 2018; Jullien et al. 2012).

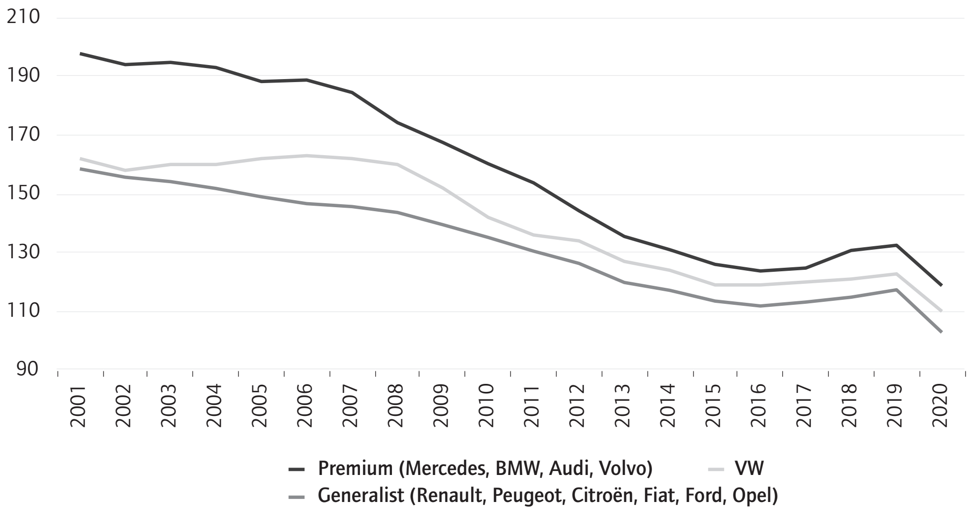
4.2 Electrified SUVs as a way out?

The paradox of the 2009 EU CO_2 regulation was that it contributed to upmarket drift and distorted competition in favour of cars that emitted more Co_2. By 2019 the average premium car, costing 47 640 euros, weighing 1690 kg (165 kg more than in 2001) and emitting 133g/km of CO_2 in the laboratory (NEDC) and 193g/km of CO_2 on the road (RD), had increased its sales by 38 per cent; while the average generalist car, costing 23 213 euros, weighing 1300 kg (109 kg more than in 2001) and emitting 117g/km of CO_2 in the laboratory (NEDC) and 160g/km of CO_2 on the road (RD), had lost 35 per cent of its sales.

The other paradox is that, since 2009, the conversion of generalist cars to the premium conception of control made them less and less green in relative terms: practically no real progress was made in reducing CO_2 emissions on the road for the generalist car although the premium car achieved slightly better results thanks to the higher penetration of diesel and direct injection petrol models. This also explains the different attitude of generalist car manufacturers during the 2017 negotiations on the new CO_2 regulation: contrary to 2008, when they challenged the premium conception of control, this time they did not have any clear competitive advantage in terms of fuel consumption. Forced to play by the same rules as the premium brands, generalist car manufacturers were much more than before in the same boat as premium car manufacturers.

With the diesel market share declining since 2015, in particular for generalist brands, the net result of this trend was that, in 2019, the average European car emitted more or less the same amount of CO_2 on the road as in 2009: 170g/km compared to 168g/km. If we consider a maximum optimisation rate of the homologation test at 10 per cent (the Commission objective for 2023), such a level of CO_2 emissions would have resulted, in 2020, in 83 billion euros of penalties for the European automotive industry. Even the official optimised NEDC emissions, of 122 g/km in 2019, would have generated penalties amounting to 40 billion euros in that same year.

Figure 13 **CO_2 emissions (NEDC) by groups of brands, 2001-2020**

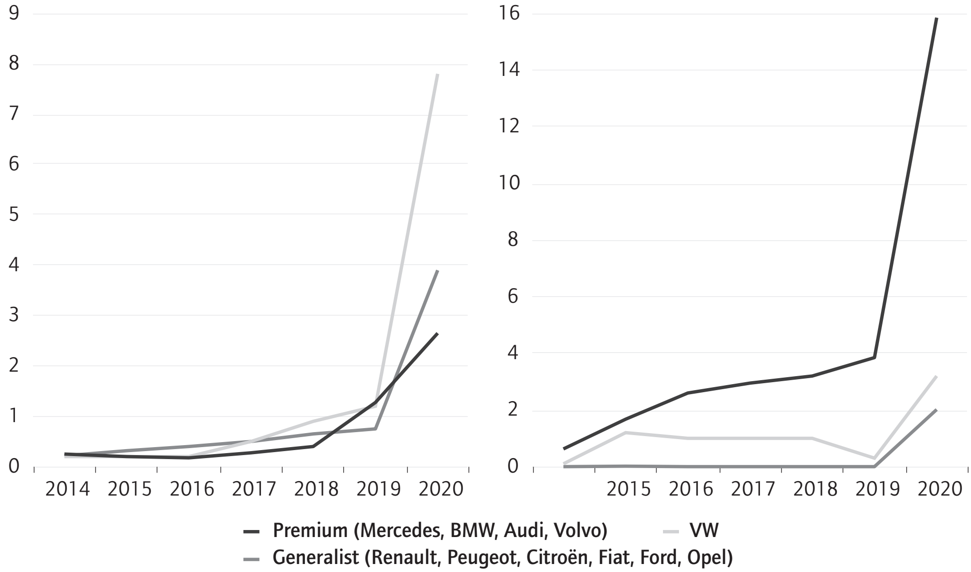


Source: EAE, ICCT.

Electrification was the only possible way of avoiding such a catastrophic scenario. It is important, however, to distinguish between BEVs, which do not have an internal combustion engine (homologated as zero emissions vehicles) and PHEVs, where a rechargeable battery and an electric engine are added to a conventional ICEV (homologated as low emissions vehicles below 50g/km of CO_2 – 40g/km on average in 2020), even if both qualify as ZLEV in respect of the super-credits.

BEVs started to be introduced in the early 2010s by generalist car manufacturers in Europe, and in particular by Renault (1.7 per cent of its total sales in 2015) and Nissan (2.2 per cent). They were initially extremely light and compact, with low levels of autonomy and often associated in this early phase with the diffusion of new mobility services. The only premium car manufacturer that was already selling BEVs in 2015 was BMW, but in smaller numbers (0.6 per cent of its total sales). German premium car manufacturers were, in general, against electrification which they deemed as a non-mature technology viable only for small urban experimental vehicles (Hildermeier and Villareal 2012).

Figure 14 **Sales of BEVs (left) and PHEVs (right), % by groups of brands, 2014-2020**



Source: EAE, ICCT.

In contrast PHEVs were, from the beginning of their diffusion, perfectly compatible with the premium conception of control as they were structurally heavier and more expensive than conventional cars due to the extra battery and electric engine. Not surprisingly, premium brands took the lead in introducing PHEVs in Europe and mainly relied on them to make the 2020 95g/km CO_2 target while generalist brands and VW pushed BEVs and improved their internal combustion engines.

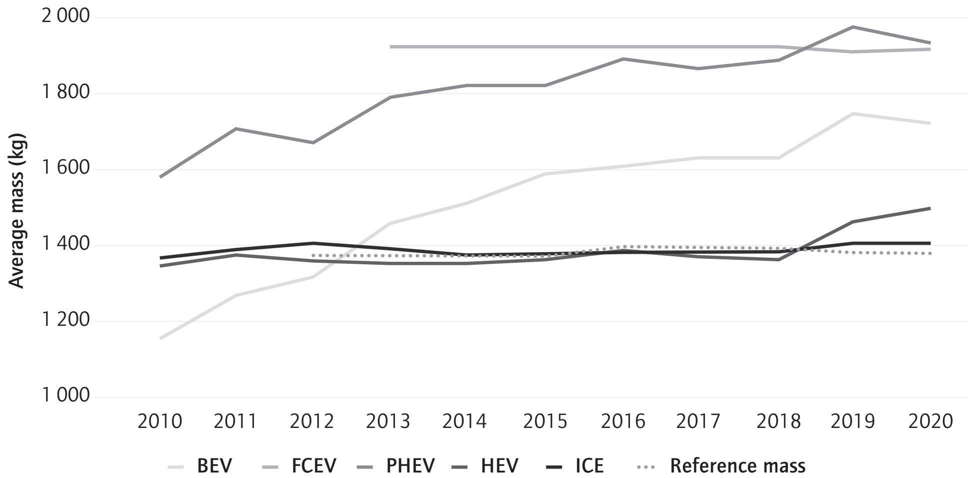
However, premium brands were rapidly catching up with generalist brands on BEV sales. Indeed, not only PHEVs but also BEVs went rapidly upmarket in the second half of the 2010s as their average weight and price grew at a much faster rate than those of the average European car. As we will see in the next section, this upmarket drift of BEVs reflected a profound transformation of the meaning and direction of electrification.

5. The environmental, economic and socio-political costs of upmarket electrification

Fifteen years ago, when the European automotive industry started to launch the first electrified models on the mass market, it was clear that BEVs could not and should not be seen as conventional cars due to their limited range and long recharging time (Jullien and Pardi 2013). The transition towards BEVs was meant, instead, to transform the automotive paradigm from personal owned mobility to shared mobility, from multipurpose vehicles to dedicated vehicles based on service business models requiring a relatively dense networks of charging stations at home and at work (Villareal 2011; Fojcik and Proff 2014; Hildermeier 2016).

The 2009 Bolloré Bluecar used by the iconic Autolib car-sharing service in Paris was a perfect example of this first generation of BEVs (Vervaeke and Calabrese 2015). The Bluecar was extremely small and compact, with no paintwork and basic interiors, weighing 1170 kg, including the 300 kg of the 30 kW battery, and had a top speed of 120 km/h and an official range of 250 km. In comparison, the Tesla Model 3, which was the best selling BEV in Europe in 2021, weighed up to 790 kg more than the Bluecar; it was also 1.4 m longer, equipped with batteries of 54 kW up to 77 kW delivering a range of between 400 and 560 km and had a top speed of up to 260 km/h. Midway between these two extremes, the evolution of the Renault Zoe, launched in 2013 as an affordable car, shows the effects of upmarket drift on EVs in Europe. Between 2012 and 2019 its battery power more than doubled, from 22 kW to 55 kW, its range grew from 200 km to 400 km, its engine power increased from 65 kW to 80 kW, the vehicle gained 75 kg of weight and its price increased by 16 per cent.

Figure 15 **Average mass in running order (kg) by type of technology, 2010-2020**



Source: T&E 2021.

Figure 15 shows how much the average BEV sold in Europe gained in mass between 2010 and 2020: from 1170 kg (i.e. the Bluecar) in 2010 to 1721 kg (i.e. the VW ID3), an increase of 47 per cent; which is higher than the PHEVs that gained 23 per cent in mass during the same period (from 1581 kg to 1951 kg).

The almost 600 kg gained by the average BEV in Europe in these 10 years reflected a drastic change in the way of conceiving BEVs and their usage. Conventional cars tend to be over-dimensioned and over-powered for everyday usage because people historically bought them as multipurpose vehicles so that the dimensions and properties of the cars reflect the most extreme usages: i.e. the few times when the whole family goes on holiday via a motorway. But for most of the time (some 98 per cent of trips), this over-dimensioned and over-powered car transports only 1.3 people on average travelling less than 50 km a day at less than 60 km per hour: the extra room, the extra weight and the extra power does not serve any purpose but to consume more fuel, emit more CO_2 and air pollutants, and occupy more space in congested urban areas.

The BEV was conceived for everyday/average urban and peri-urban usage so that it would be both efficient (using less energy and requiring relatively small batteries) and affordable, because the weight of a car is the most important factor in determining the range of a BEV while the size of the battery is the most important factor in determining its price. Contrary to a conventional car, increasing the range and the size of an electric car for the most extreme usages is not only very expensive, but it also drastically reduces the energy efficiency of the car because it adds so much more weight than in the case of conventional ICEVs.

The European upmarket drift of BEVs reflected therefore a shift from them being conceived as new types of vehicle dimensioned for the average usage of people (with the parallel development of mobility services to cover for exceptional usages) to being conceived as electrified versions of already heavy and powerful multipurpose cars, making these cars even heavier and even more powerful.

Once again, this upmarket drift does not necessarily reflect consumer preference, technological constraints or technological progress (although in battery technology, energy density and efficiency improvements do matter). It is largely due to the historical result of the institutionalisation of a premium conception of control at European level in the 1990s and 2000s, and its preservation after Dieselgate despite clear evidence of a fundamental contradiction between upmarket drift and the green transition.

The comparison with China, the main world market for EVs, and in particular for BEVs, offers an instructive perspective. The average BEV in China weighs 210 kg less than an equivalent Chinese ICEV and 390 kg less than the average European BEV (IEA 2019: 53-54). The highest selling EV model (BEVs and PHEVs) in 2021 was the SAIC-GM Wuling Hongguang Mini which has a basic range of 120 km, a top speed of 100 km/h, a mass of only 700 kg and a price below 5000 euros (without subsidies).

The heavier a BEV, the bigger the battery needed to propel it but, since the battery is also very heavy (and the most expensive component of the car – 40 per cent on average of the total cost), this adds further weight (and cost). In turn, this requires more technology (more efficient braking systems, a more powerful electric engine, more active and passive safety technology, more premium features to justify the price), all of which adds further weight (and also cost).

In other words, the upmarket drift of a BEV has increased its weight and price by a much higher proportion than the upmarket drift of a conventional car. The electrified versions of conventional cars are, on average, 400 kg heavier and 10 000 euros more expensive than their petrol versions and cannot be currently sold in Europe without generous state subsidies. In contrast, the battery electric Chinese mini-cars are already cheaper to buy than equivalent petrol cars and are the best sold BEVs in China without any subsidy.

Electric upmarket drift has multiple consequences – environmental (less efficient and more polluting vehicles); economic (more expensive vehicles further distorting competition between premium and generalist car manufacturers); and social (less affordable green mobility and the social exclusion of middle and working classes) and political ones (discrimination in favour of wealthier countries and households). We look at each of these in the following sections.

5.1 The environmental consequences of heavy electric vehicles

Adding 600 kg to a BEV and 400 kg to a PHEV in ten years has significantly reduced the environmental benefits of an electric vehicle. Doubling the average size of an EV battery has negative consequences for all its life cycle.

First, some of the materials needed to manufacture batteries, in particular cobalt and lithium, but also nickel, are rare and their extraction is itself polluting. By increasing the size of the average EV battery, the upmarket trend has contributed to increases in the prices of these materials and a reduction of their availability, potentially undermining the economic viability of batteries in car production, in particular in the case of an accelerated transition which sees 2035 sales as being made up of 100 per cent EVs (Jetin 2020). At the time of writing (March 2022), the cost of the raw materials required to manufacture the most popular lithium-ion batteries has increased during the last two years (since January 2020) by 326 per cent for nickel-cobalt-manganese (NCM) batteries and 708 per cent for lithium ferro-phosphate (LFP) ones.[8]

Second, battery production requires a lot of energy. Currently this production is mainly carried out in countries where energy production has high CO_2 intensity, like China which, in 2020, represented 75 per cent of the global production of batteries for cars.

EU production of batteries remains at the start, but it is planned to grow substantially in the next years. Gigafactories tend to be located close to car assembly factories due

8. Source: https://www.benchmarkminerals.com/lithium-ion-battery-raw-material-index/

to the high cost of moving the 300-600 kg batteries and also the general advantages of clustering and proximity for better integration of the battery in the car and in the manufacturing process. The problem is that most car assembly factories in Europe are located in relatively high CO_2 intensity countries (more than 200g/kW of CO_2 on average and more than 300g/kW of CO_2 for Germany, Poland and Hungary which, so far, concentrate 50 per cent of the total announced battery capacity for 2030).[9] Labour cost is another important factor for location choice, with most of the low wage countries with large automotive industries in the EU being heavily reliant on coal to produce their energy (Poland, Czechia and Romania, where around 15 per cent of the European production of cars is located).

Given the current locations of battery production, EVs come with a relatively high CO_2 debt when they start to be used and it takes several years before they emit less CO_2 than equivalent ICEVs. The debt is much bigger for heavier cars. For instance, for a Tesla S manufactured and used in China (550g/kW of CO_2), the debt amounts to 15 tons of CO_2 and it takes 139 400 km to pay it off (Arval 2019: 67-86).

Third, while BEVs do not emit CO_2, they use energy whose production emits CO_2. In 2018 the EU energy sector emitted 3.3 billion tons of greenhouse gases. This is much less than the 4.3 billion tons emitted in 1990 but still more than the 0.9 billion tons emitted by the transport sector in 2018. Doubling the size of the battery to carry much heavier vehicles can amount to a doubling of the amount of energy used by BEVs and, therefore, their related CO_2 emissions (Berjoza and Jurgena 2017: 1391).

Fourth, cars generate harmful fine particles ($PM_{2.5}$ and PM_{10}) mainly through brake, tyre and road wear (on average 60 per cent of total PM emissions). This does not change with BEVs and PHEVs (AQEG 2019). Extra weight increases the wear, further contributing to air pollution. Bigger cars also take up more space, thus increasing urban congestion which also raises transport emissions.

Fifth, while all the previous points also concern PHEVs which, in 2021, represented half of the total European sales of EVs, the extra weight carried by PHEVs means that, when they are propelled by their internal combustion engines, they emit much more CO_2 than their equivalent (much lighter) petrol and diesel versions. All recent reports by environmental NGOs, based both on consumer data and laboratory tests, have shown that the rate of optimisation of the homologation of recent PHEVs, in comparison with real drive consumption, is on average 220 per cent and can rise as high as 400 per cent (ICCT 2020).

Sixth, heavier BEVs and PHEVs are much more expensive that lighter BEVs and PHEVs and equivalent ICEVs. This lack of affordability is one of the major obstacles to the diffusion of such vehicles in Europe, in particular in southern European countries and in the new Member States that, during the last twenty years, have become the most important net contributors to the growth of CO_2 emissions in the transport sector.

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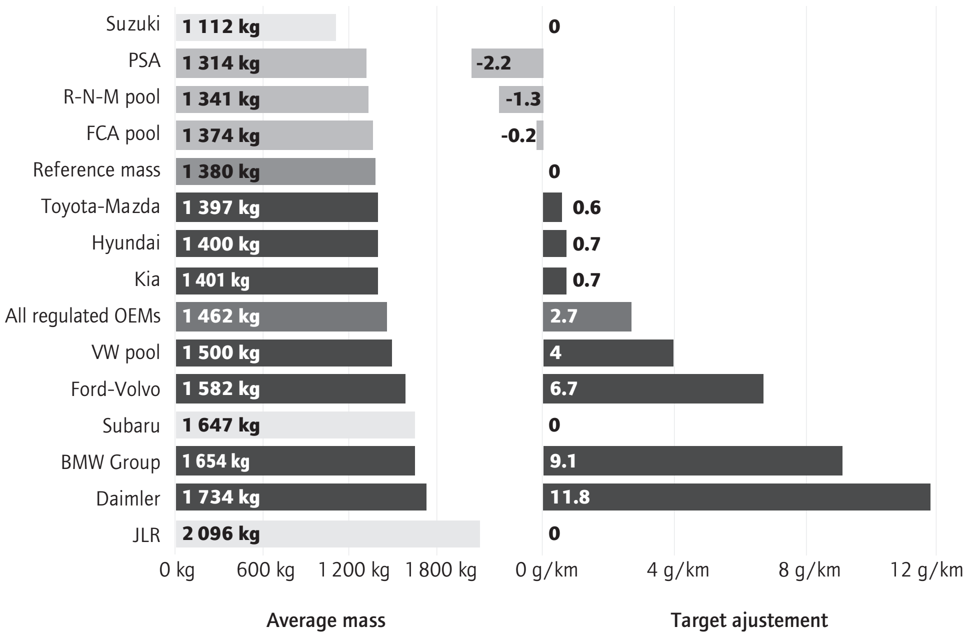
9. Source: https://www.eea.europa.eu/data-and-maps/indicators/overview-of-the-electricity-production-3/assessment

5.2 The economic consequences of accelerated upmarket drift

The upmarket trend on electrification is making the average European car once again (but much more quickly than before) heavier, more powerful and more expensive. In order to comply with the 2020 target of 95g/km of CO_2 (on 95 per cent of sales), European car manufacturers increased the share of EVs from 3 per cent in 2019 to 11.9 per cent in 2020 (6 per cent BEVs and 5 per cent PHEVs). As a result of this higher share of EVs, the weight of the average European car increased (in one year) by 3 per cent, engine power by 4 per cent and price by 5 per cent (which is double the average annual rate between 2001 and 2019 – see figures 8, 9 and 10 above).

In just one year of this accelerated upmarket drift, the premium group increased its market share by 7 per cent while the generalist group's share declined by 4 per cent with VW slightly increasing its share by less than 1 per cent (see Figure 11 above). The premium group also had a significant advantage in terms of meeting their CO_2 targets in 2020 and 2021 by combining higher sales of extremely heavy PHEVs with a proportional weakening of their weight-based targets. For 2021, T&E calculated that the mass adjustment of the premium car manufacturers represented on average 27 per cent of their compliance efforts (more than their increased sales of BEVs), while this figure was 17 per cent for VW. For the generalist group, mass adjustment had a negative impact (making their target more stringent), as shown by Figure 16 (see also T&E 2021).

Figure 16 **Average mass and resulting target adjustment by car manufacturer in 2020**



Source: T&E 2021.

By distorting competition, the 'accelerated' upmarket drift brought about by the combined effects of electrification and the adverse effects of the CO_2 regulation that, as we have seen, favours structurally more polluting vehicles is bound to have significant socio-economic consequences.

The effects of the previous 'normal' upmarket drift on the production volume and localisation of the main European car manufacturers during 2000-2017 resulted in German premium car manufacturers (Volkswagen, Daimler and BMW) significantly increasing their production volume in Europe (by 2.2 million cars; an increase of 40 per cent), mainly in Germany (up 1.1 million; 30 per cent) and in central and east European countries (up 1 million; 180 per cent). In contrast, generalist car manufacturers, including the German ones (Ford and Opel), lost production volume (totalling 2.6 million cars, a drop of 29 per cent) in particular in their domestic bases[10] (2.3 million; 34 per cent) and in other high wage EU15 countries (1.6 million; 45 per cent), with a significant amount of this lost production being relocated to central and east European countries, Turkey and Morocco (an increase of 1.3 million cars; 160 per cent).

The economic consequences of these massive production losses and relocations were particularly difficult for the national automotive industries in France and Italy where 108 000[11] direct jobs have been lost; while upmarket drift has helped the industry in Germany to preserve its hegemonic position in the European value chain.

Table 1 **The automotive industries of Germany, France and Italy in 2000 and 2019 (production, output, gross value added and employment)**

	Germany	France	Italy
Production (2019)	**5 030 351** (28% of EU28)	**2 202 460** (12% of EU28)	**854 000** (5% of EU28)
(2000-2019)	**-496 084** (-9%)	**-1 145 901** (-34%)	**-884 315** (-51%)
Output (2019) Billion €	**411** (42% of EU28)	**69** (7% of EU28)	**63** (6% of EU28)
(2000-2019)	**+193** (+89%)	**-1** (-2%)	**+16** (+33%)
Gross Value Added (2019) Billion €	**137** (54% of EU28)	**14** (5.5% of EU28)	**14** (5.56% of EU28)
(2000-2019)	**+80** (+144%)	**-4** (-22%)	**+2.5** (+22%)
Employment* (2019)	916 000	106 000	177 000
(2000-2019)	**+30 000** (+3%)	**-80 000** (-43%)	**-28 000** (-14%)

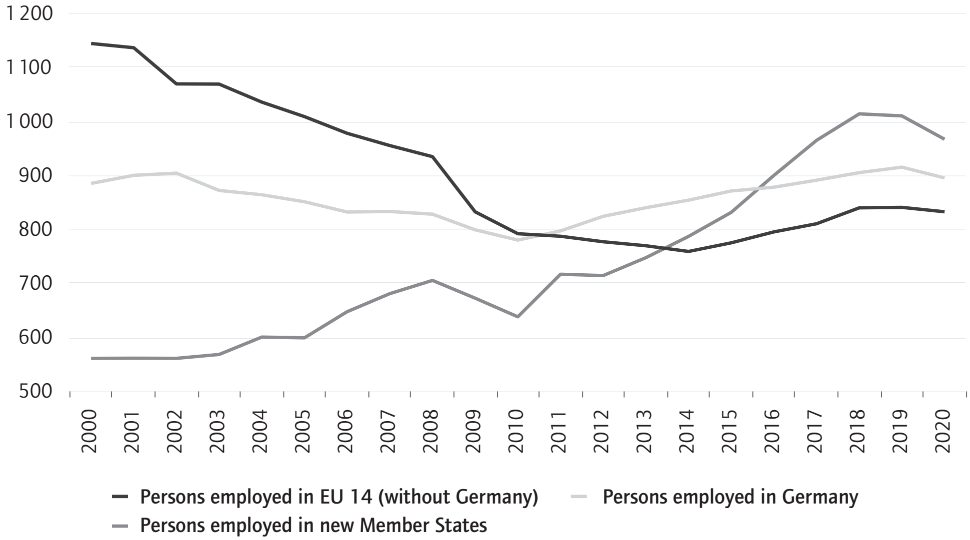
* Annual detailed enterprise statistics for industry.
Source: Eurostat.

10. In the case of Opel-Vauxhall and Ford Europe we refer here to Germany as the domestic base.
11. On the basis of data from Eurostat's annual detailed enterprise statistics for industry.

We note in particular how the German automotive industry, despite a decline of 9 per cent in the production volume of motor vehicles between 2000 and 2019 (due mainly to the collapse of Opel), increased its output by 89 per cent (193 billion euros) and gross value added by 144 per cent (80 billion euros). In contrast, France and Italy have seen their production plummet (by 34 per cent and 51 per cent, respectively). Gross value added declined in France (22 per cent) but increased in Italy (22 per cent) due to its car parts sector (Manello et al. 2016).

This stark contrast in the evolution of the main premium industry (in Germany) and of the two main generalist ones (in France and Italy) within Europe highlights the considerable economic consequences that upmarket drift has had in terms of restructuring and deindustrialisation.

Figure 17 **People employed in the automotive industry in Europe in the EU14 (without Germany), in Germany and in the new Member States (EU13), 2000-2020**



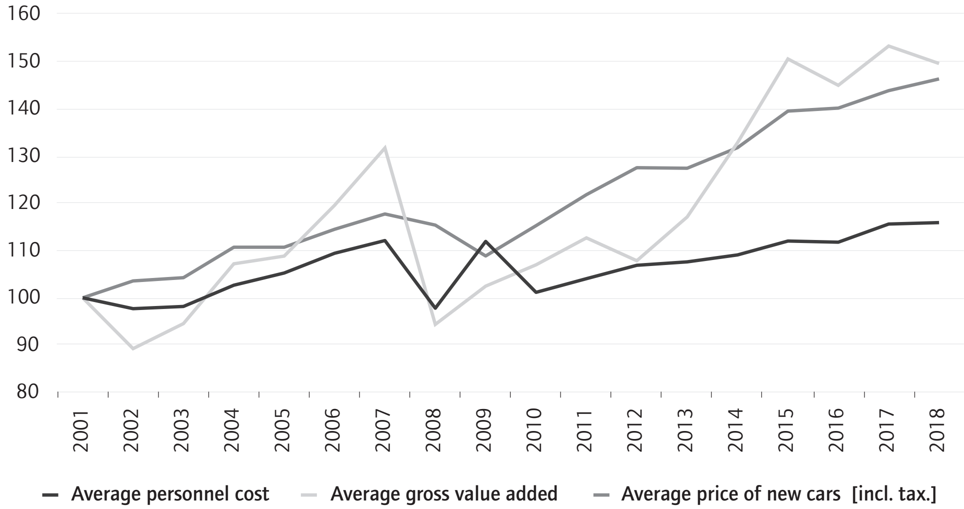
Source: Eurostat.

As Figure 17 shows, the combined effects of the waves of relocation of production towards central and east European countries and upmarket drift has been negative for employment for most of western Europe. With the only exception of Germany, where automotive employment has slightly increased during this period (by 30 000, 3 per cent), industry employment in high wage EU14 countries has substantially decreased (by 312 000), while employment in the low wage new Member States has increased (by 406 000).

This trend, which is the direct consequence of the relocation of production from high wage to low wage countries, has generated a zero sum game where almost each job created in the new Member States corresponds to a job eliminated in the EU15. The competition here – for investment, products and projects – is not between different companies but between different factories and R&D facilities within the same transnational companies. In each of these 'beauty contests', the winner tends to be the group of workers, trade unions or national governments that make most concessions to reduce labour costs and workers' protection and to increase labour flexibility.

The aggregate result has been an increasing disconnection between productivity gains and wages (see Figure 18). Between 2001 and 2018, the average gross value added (per person employed) generated by the European automotive industry outside Germany increased by 50 per cent, propelled by upmarket drift, while average personnel costs increased by only 16 per cent. This was less than half the rate of European inflation during the same period (36 per cent), meaning that real average personnel costs in fact decreased by 20 percentage points.

Figure 18 **Average personnel cost, gross value added and the price of new cars in the European automotive industry (other than Germany), 2001-2018**



Note: EU28 without Germany.
Source: Annual detailed enterprise statistics for industry, Eurostat. Author's calculations.

It is interesting to note that, during the same period, the average price of new cars increased by 46 per cent, three times higher than average personnel costs, illustrating the disconnection of the Fordist link between mass car sales and high wages, and between consumers and workers.

It is still too early to measure the economic consequences of the acceleration in upmarket drift pushed by electrification. In particular, the Covid-19 crisis in 2020 and 2021 and the chip shortage crisis of 2021 and 2022 have created a very unusual economic environment in which most of the costs of these crises have been absorbed by government measures via temporary unemployment and subsidies for car sales.

What we do expect is a generalised intensification of the trends associated with upmarket drift: more relocation of lower added value activities in engineering, assembly and parts manufacturing towards low and ultra-low wage countries; more pressure on labour costs both in high, low and ultra-low wage countries; and faster and, in some cases, massive reduction of employment (collective redundancies) for low-skilled and semi-skilled workers. In other words, we expect the European automotive industry to 'digest' the costs of electrification in the next 5-10 years in the same way it has digested the costs of dieselisation during the last 15-20 years.

5.3 The social and political costs of even more expensive cars

When we compare the sales of new cars in the EU28 in 2001 and 2019, the figures appear static (up by 0.7 per cent) but, relative to the EU28 population, which has increased by 5.4 per cent, they have declined by 4.5 per cent. During this period the number of cars on the road in Europe kept on increasing: from 201 million to 265 million (an increase of 31 per cent in total and of 25 per cent when expressed per 1000 inhabitants).

Table 2 **New car sales and passenger cars per 1000 inhabitants in EU28 in 2000 and 2019**

	2000	2019	%
EU28 population (millions)	499	526	5.4%
New car sales	15 366 229	15 467 336	0.7%
New cars per 1000 inhabitants	30.7	29.4	-4.5%
Passenger cars per 1000 inhabitants	414	516	24.6%

Source: Eurostat, OICA, ACEA.

We can see in these contrasting figures some of the causes of the growing CO_2 emissions from the passenger car sector in Europe during this period (a rise of 22 per cent between 1990 and 2020) and of the failure of the EU CO_2 regulation to tame them.

On the one hand, the new cars that were expected to green the European car fleet during this period were not in fact much more green than the cars they were replacing: because they were structurally more polluting (heavier and more powerful), the benefits of their new technologies (diesel and direct injection petrol) were almost completely erased.

On the other hand, these new cars were also becoming more expensive which made it harder for the average European household to buy them, such that the rate of renewal of the car fleet slowed down (from 7.6 per cent to 5.8 per cent). But, at the same time, and in particular in the new Member States whose economies were growing much faster than the EU28 average, the need for cars was either growing (EU15) or booming (EU13). This unregulated need could not be satisfied by relatively less emitting new cars but by older cheaper second-hand ones. Consequently, the average age of the car fleet in Europe grew at a much faster pace than before (from 6.8 years in 2000 to 12 years in 2020).[12] The net result was much more cars (a rise of 25 per cent between 2000 and 2019) and much more relatively high polluting older cars per 1000 inhabitants (an increase of 5.2 years on average), which inevitably resulted in more CO_2 emissions rather than less.

If we break down the Single Market into different groups of national markets we can see that important national differences exist behind this general trend and that upmarket drift did not only slow down the uptake of new greener cars but it also significantly widened inequalities in access to new and greener cars between the wealthier and the poorer European countries.

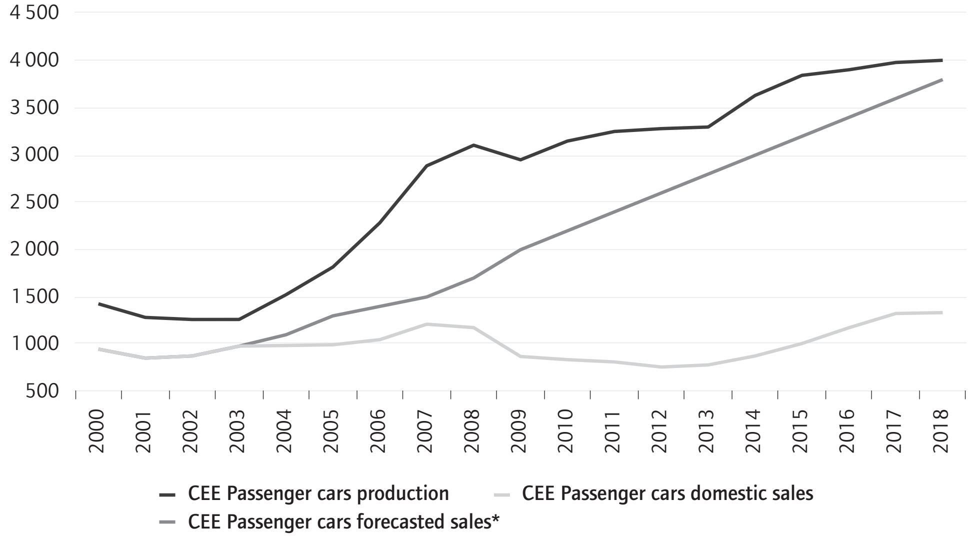
In northern European countries, the upmarket drift of the average new car sold (increase of 52 per cent in price and 11 per cent in mass between 2001 and 2019[13]) has not affected the sales of new cars which have fully recovered after the 2008-2010 crisis (overall increase of 5 per cent between 2001 and 2019). It was also here where most EVs were sold in 2020 (71 per cent of total sales of EVs in the EU28; a market share of 14 per cent for EVs). Their impact in terms of upmarket drift was clear (a rise of 7 per cent in price and of 5 per cent in weight in one year) but, thanks to widespread generous state subsidies, new car sales were little affected.

In southern European countries the impact of upmarket drift on new car sales was highly significant. When we look at the rate of increase in price (55 per cent) and weight (10 per cent) between 2001 and 2019, we do not see any difference with northern European countries, even though cars here were cheaper in absolute terms (29 per cent lower) as well as lighter (they weighed 8 per cent less). But, at these fast growing prices, southern European populations found it more and more difficult to buy new cars so they adjusted to upmarket drift by buying fewer of them: a drop of 52 per cent at the bottom of the crisis in 2013; and one of 17 per cent in 2019 in comparison with 2001. If electric uptake here was logically much slower than in northern European countries – a market share of only 4.8 per cent in 2020, 10 per cent of the total EU28 – its upmarket drift was more pronounced: an increase of 6 per cent in price and 3 per cent in weight in 2020.

For the 13 new Member States that joined the EU mainly between 2004 and 2007, upmarket drift was also strong but it only started in the different groups of countries after joining the European Union, highlighting the structuring role of the EU regulatory framework. Overall, between 2001 and 2019 the average mass of new cars grew by 24 per cent and the average price by 48 per cent. Sales, that were increasing rapidly before entering the EU, started to decline after EU entry before picking up again in 2014. Back in 2004, when these countries started to join the EU, European economic authorities anticipated the take-off of new car sales and justified the massive investment to create new production capacity on these grounds (Boillot and Lepape 2004).

12. Source: ACEA: https://www.eea.europa.eu/data-and-maps/indicators/average-age-of-the-vehicle-fleet/average-age-of-the-vehicle-8
13. Source: EAE, ICCT, author's calculations.

Figure 19 **Production of passenger cars and domestic sales in central and east European countries, 2000-2018**



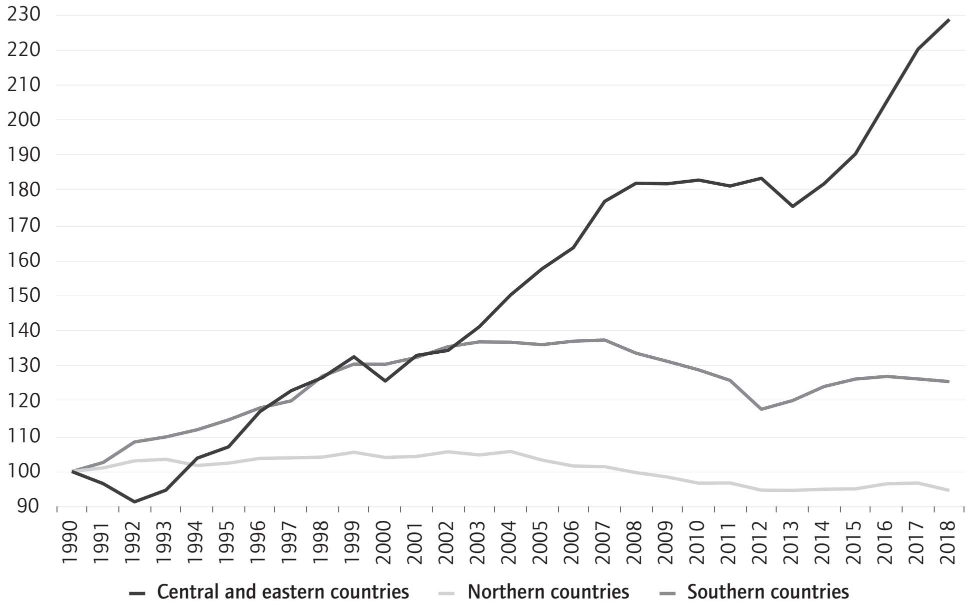
* As forecasted in Boillot and Lepape (2004).
Source: OICA, ACEA.

As we can see from Figure 19, this take-off never actually took place. The combination of upmarket drift and of massive second-hand car imports killed the market for new cars while export-led automobile production rapidly increased and could only be justified in terms of the relocation of production from EU15 countries.

The competitive advantage of these production sites lay no longer in that they were located in high growth markets but, instead, in the presence of a cheap and flexible workforce to produce the compact and small cars that European car manufacturers would now relocate from their high wage countries: from market seeking, European integration turned into efficiency seeking.

It Is very difficult to imagine how these countries could realistically board the Green Deal 'train' towards carbon neutrality in 2050 under these conditions: they have the oldest, most polluting, rapidly ageing and fast-growing car fleet in Europe (mainly via second-hand car imports); average annual per person revenues are still 63 per cent below the European average some 15-18 years after having joined the European Union, but the average new car price is only 21 per cent below the average European level. Moreover, this is increasing faster than average per person revenues. Even if we consider that the EVs sold in the EU15 will eventually flow as second-hand cars to these countries, in the current circumstances of accelerated upmarket drift it will take decades before this could realistically happen. In the meantime, social and political opposition to the EU Green Deal has been mounting in these countries where the degree of economic dependency on fossil fuels is extremely high (Gažo 2022).

Figure 20 **Greenhouse gases from fuel combustion in cars by groups of EU28 countries, 1990-2018**



Note: Southern European countries include France. Central and eastern countries include Bulgaria, Czechia, Estonia, Latvia, Lithuania, Hungary, Poland, Romania, Slovenia and Slovakia.
Source: EEA, author's own calculations.

Figure 20 illustrates that, in the case of central and east European countries, CO_2 emissions from cars, rather than diminishing by 40 per cent between 1990 and 2018 (in order to be on track with the 100 per cent reduction target by 2050 or with the most recent 55 per cent target for 2030), have more than doubled (an increase of 240 per cent). Most of this staggering growth occurred after integration in the European Union and was only temporarily slowed by the harsh effects of the financial crisis between 2008 and 2013.

Figure 20 also highlights the failure of upmarket drift to drive down CO_2 emissions everywhere else in Europe, including the northern European countries where emissions have stagnated despite relatively widespread access to new cars and quite active policies supporting the diffusion of greener electromobility. In southern European countries, emissions were 25 per cent higher in 2018 than in 1990 and, if they have slightly declined since 2007, this was due almost exclusively to the long term impact of the financial crisis of 2008 and of the Eurozone crisis of 2009-2011, resulting in fewer kilometres being travelled by cars on average rather than from any greening of the car fleet.

6. The 'Fit for 55' EU proposal: towards ultra-accelerated upmarket drift in electrification

Following the launch of the European Green Deal plan by the European Union in 2019 to reach climate neutrality in 2050, and the publication in 2020 of an impact assessment on 'Stepping up Europe's climate ambition in 2030' to reach at least a 55 per cent reduction in CO_2 emissions by 2030 (compared to 1990), the European Commission proposed in July 2021 a 'Fit for 55' revision of the CO_2 regulation for new cars and vans. This entails a hardening of the CO_2 target for 2030 – from the 37.5 per cent reduction agreed in 2017 to a 55 per cent reduction target for cars and from 31 per cent to 50 per cent for vans; and a 100 per cent reduction target for 2035, marking the end of the internal combustion engine.

The 'Fit for 55' proposal is a lucid recognition of the failures of the CO_2 regulatory packages of the last 30 years. But it also keeps reinforcing the upmarket trend that has significantly contributed to these past failures and it does not challenge the premium conception of control behind it.

For instance, the emphasis is once again put on the development of the highest possible technology to push EVs towards greater range (larger batteries) and better connectivity (data management, automated cars). In the impact assessment annexed to the proposed regulation there is an explicit reference to Tesla as the model to follow by European car manufacturers (European Commission 2021: 15). Yet, in the chapter following this citation, 'affordability' is highlighted as the main obstacle to the uptake of EVs in Europe. It is noted that, while the price of batteries fell by 87 per cent between 2010 and 2019:

> … the average Battery Electric Vehicles (BEV) price increased by more than 40% between 2011 and 2019 as manufacturers were focusing on premium and larger mid-size cars, leaving very few offerings in the entry-level segments. (European Commission 2021: 16)

It is also noted that the average BEV sold in Europe in 2019 was 52 per cent more expensive than in China and 10 per cent more expensive than in the US. The impact assessment concludes that there is a high risk of failure to reach the target of climate neutrality in 2050 due to the lack of 'affordability' and that 'the risk is highest for lower income groups, as they also have less access to financing possibilities' (European Commission 2021: 17).

But nothing is proposed to mitigate this risk. Rather the contrary, since the weight-based CO_2 targets that have fuelled this upmarket drift towards more expensive cars, and that are now playing an even bigger role in favour of premium brands due to the accelerated upmarket drift driven by electrification, are not questioned.

The 'Fit for 55' regulation is bound to lead to an ultra-acceleration of upmarket drift, but its impact assessment fails to make any sense of it. It argues that, in the end, neither consumers nor workers will be affected. It anticipates that 'affordability' problems would only concern the two lowest income groups (quintiles 1 and 2) when they buy in the 'larger vehicle segments, mainly PHEV and FCEV [fuel cell eVs]', while 'BEV [will] remain or become affordable with time' (European Commission 2021: 54). It also claims that these expectations are equally valid in all EU countries and that all EU consumers, and in particular those in lower income groups, will benefit from lower usage costs despite higher upfront costs (notably via access to second-hand cars).

Concerning workers, the impact assessment anticipates that only 4000 jobs will be lost in the European automotive industry by 2030 (a drop of 0.16 per cent), growing to 13 000 jobs lost by 2035 and 36 000 by 2040 (down 1.65 per cent), against a net gain of almost 500 000 jobs by 2040 across the whole economy. These forecasts are made on the assumptions that total sales of new cars will remain stable in the future and that the value added per car in the industry will substantially increase with the shift from ICEVs to EVs.

We have seen before that, under the previous upmarket drift driven by dieselisation, sales declined and were, most of the time, significantly below their 2000-2005 level due to cyclical economic crises. This is despite the enlargement of the Single Market, the demographic growth of the European Union and the integration of emerging countries with a strong potential demand for new cars. How is it possible that, with the ultra-accelerated upmarket drift implied by rapid electrification, sales will remain stable or only slightly decline during the next 10-15 years?

This question was already pertinent before the Covid-19 crisis, the invasion of Ukraine by Russia and the surge in prices which is seeing forecast inflation for the Euro zone reach 7.5 per cent for 2022. But now it seems even more unlikely that sales of new cars will ever recover their pre Covid-19 crisis level as price inflation is particularly strong for all the raw materials used to manufacture EVs and batteries, as well as for the energy used both to produce and to use them. As we have already stressed, the prices of the raw materials used by the most popular lithium-ion batteries have drastically increased since 2020: by 326 per cent for NCM batteries and 708 per cent for LFP ones.[14] This pushes the price of BEVs further up, making them less and less affordable.

Contrary to China, where electrification is shaped by different conceptions of control and where consumers can buy BEVs that are significantly cheaper to acquire and to use than ICEVs and PHEVs, such an option to counter the inflationary pressure on the automotive industry is not available in Europe. The combined effect of these generalised inflationary pressures and of ultra-accelerated upmarket drift in electrification will be that prices of new cars grow much faster than before; and we already have substantial evidence of this in 2021 and 2022.

All the consequences of upmarket drift and of its accelerated early-electrification version (for 2020) that we have identified above will inevitably be amplified. As prices grow and the market shrinks, competition will be further distorted in favour of premium brands. EVs will become heavier and more powerful, drastically reducing their positive

14. Source: https://www.benchmarkminerals.com/lithium-ion-battery-raw-material-index/

environmental impact. The pressures to reduce costs, quantified in December 2021 by the CEO of Stellantis, Carlos Tavares, at 10 per cent per year,[15] probably now growing to 15 per cent per year, will further increase throughout the whole value chain affecting all countries. This will push further relocations in the lower segments of value chains; employment cuts at a much more rapid pace than anticipated, leading probably to redundancies and factory closures in particular in southern European countries; and generalised pressure on labour costs and wages while the cost of living is rising extremely quickly. The rate of renewal of the European car fleet will further slow, amplifying the divide between, on the one hand, the fewer wealthy owners and users of EVs who frequently benefit from generous state subsidies, fiscal advantages, free public parking, free access to city centres, preferential road lanes and lower usage costs due to relatively low energy and maintenance costs; and, on the other, the growing majority of European citizens excluded from the Green Deal who will have to bear the economic and social costs of holding on to ageing ICEVs whose negative externalities are and will be increasingly penalised and taxed.

This divide will also increase between the wealthier northern European countries and southern, central and east European ones. Inflation will eventually lead the European Central Bank to raise interest rates, increasing the cost of national debts (which have significantly grown during the Covid-19 crisis) as well as the ‘spread’ (the relative cost of the debt) between exporting countries with a trade surplus, like Germany, and importing countries with trade deficits, like Italy and France. Under these conditions the respective capacities of these countries to finance the green transition, decarbonise their economies and deal with the economic and social consequences of accelerated electrification will further diverge. How this divergence will translate in political terms remains to be seen, but there is no doubt that the risk of seeing more populist anti-EU parties taking power in Europe is very high.

If such a scenario, which is unfortunately much more realistic than the optimistic narratives proposed by global consultant companies and by the European Commission, materialises in the near future, or even if only some parts of it do, then the already difficult path towards climate neutrality for 2050 will become even more difficult, if not impossible. Furthermore, its economic, social and political costs, which are already significant, will become even more important, if not unbearable.

Conclusion

In this chapter we have approached the electrification of the European automotive industry from a historical perspective. We have looked at the causes of the past failures in reducing CO_2 emissions in the transport sector in Europe. We have analysed how these past failures have translated into the current electrification of new car sales. And we have characterised from this perspective the foreseeable consequences of this fast track towards electromobility for national industries, automotive employment, citizens’

15. Source: 2021 Reuters Next Conference.

access to mobility and, more generally, on the socio-political viability of the EU Green Deal and of the green transition towards a carbon neutral economy and society.

We have shown that the past failures in reducing CO_2 transport emissions can be traced back to the early capture by the premium automotive industry of the EU's technical and environmental regulations for new cars in the 1990s and 2000s. Rather than pushing the European industry to reduce the mass and the engine power of new cars sold in the Single Market – the two most important factors affecting fuel consumption and CO_2 emissions – EU regulations have driven the industry in the opposite direction: between 2001 and 2020 the mass of the average new European car increased by 15 per cent, engine power by 43 per cent and price by 60 per cent.

We have seen how this regulatory upmarket drift has been shaped both by the harmonisation of all technical norms towards the highest possible international standards and by the weight-based CO_2 standards introduced in 2009, which de facto prevented generalist brands from going downmarket to reduce CO_2 emissions.

We then analysed the 2015 Dieselgate scandal as the logical outcome of upmarket drift that was aggravated by the asymmetry between fuel efficiency and pollution norms. By adding so much weight and power to the average new car, it became impossible for the European industry to achieve the CO_2 targets set by the European Commission without cheating. Dieselgate revealed this structural contradiction and should have led to the deinstitutionalisation of the premium conception of control at European level, recognising that it was incapable of delivering the expected reductions in CO_2 transport emissions.

Yet, the total preservation by the European Commission of the premium conception of control meant that electrification has simply substituted dieselisation, without any change in business models and product architectures. If in Europe, as stated by the EU's 'Fit for 55' impact study, BEVs are 52 per cent more expensive and almost 500 kg heavier than in China, it is because we are electrifying conventional multipurpose vehicles rather than creating new energy vehicles.

We have argued that what is particularly disrupting in the current process of rapid or ultra-rapid electrification, reflected by the 'Fit for 55' package, is not electrification per se but the combination of electrification and upmarket drift.

While there is no doubt that electrification will eventually reduce the environmental impact of upmarket drift, there is also no doubt that upmarket drift will also drastically reduce the environmental benefits of electrification. Even more than for ICEVs, heavier and more powerful BEVs and PHEVs drastically diminish the energy efficiency of these vehicles and sharply increase their cost and price.

The impact of the combination of electrification and upmarket drift on the European market is an acceleration in the latter. In 2020, the 8 per cent extra market share gained by BEVs and PHEVs doubled the speed at which the average mass, engine power and price of new cars in Europe had increased during the previous twenty years.

With the EU 'Fit for 55' proposal of phasing out ICEVs, hybrid EVs and PHEVs by 2035, combined with the introduction of the Euro 7 norm in 2026, the most probable outcome is an almost 100 per cent market share for BEVs in 2030. Judging by the announcements which have been made by European OEMs in terms of product development and platform strategies, almost all going towards a 100 per cent full electric range by 2030, it seems a fair assumption that we are moving in this direction. What we should be preparing for is ultra-accelerated upmarket drift whose impact in the short-term (2022-2030) will be much more disruptive than what we have documented for the period 2001-2019.

The road to carbon neutrality by 2050 is not an easy one. But if we move towards the technology of the future – electrification – with the same institutions and business models of the past, then it becomes an extremely difficult one. This is particularly the case when these institutions (the EU regulatory framework) and these business models (the premium conception of control) have been responsible for the rising CO_2 emissions in the European transport sector since 1990.

The main short-term challenges that are ahead of us are making BEVs affordable, in particular for households in southern and central and eastern Europe; and providing a sustainable way for these countries to be included in the EU Green Deal, also as producers of such vehicles. These challenges should be clearly recognised by the European institutions as the main priorities and should be taken up by the European generalist car manufacturers that, in the past, were historically successful in going downmarket by innovating in product designs and technologies.

There is also a real risk that, if European generalist car manufacturers completely move away from the entry-level market, then Chinese generalist car manufacturers will take their place. The main non-trade barrier that has prevented Chinese car manufacturers – such as Geely, Byd, Chery and JAC – from entering the European market is the technology of the internal combustion engine. With battery technology, however, they have already leapfrogged European car manufacturers and are ready to attack their market shares.

To avoid such a scenario, and more generally the highly disruptive consequences of accelerated upmarket drift in electrification, we think that two relatively simple amendments to the CO_2 regulation in the 'Fit for 55' package could bring the European automotive industry back to a more sustainable path:

- First, as has also been requested by T&E (2021), the leading environmental NGO in Brussels, weight-based CO_2 standards should be phased out as soon as possible;
- Second, energy efficiency should be introduced as a key parameter for evaluating the actual contribution of electric vehicles to the reduction of CO_2 emissions and calculating the average CO_2 emissions of new car sales.

These two amendments would already be sufficient to push the industry finally to reduce the mass, the power and the price of the average European car.

It is clear, however, that such a radical shift in the direction of the European industry (from upmarket to downmarket) would also imply other important institutional changes. Two in particular would be crucially important.

First, the technical regulation (whole vehicle type approval) should be adjusted to make such a downmarket shift possible. We could take example here from the Japanese regulations that have special rules and downgraded parameters for the micro 'key cars' that dominate the entry-level Japanese market and that have largely contributed to its greening.

Second, the competition rules of the Single Market should be made much more flexible so that market failures, such as the non-development of markets for new cars in the new Member States (but also the strong decline in southern European markets) could be addressed by ad hoc measures combining fiscal, environmental and industrial policies and regulations.

The current situation in which the average new car sold in the new Member States is just 20 per cent cheaper than the average European car, while average per capita revenues are 60 per cent lower than the European average, is an economic, social and environmental constraint, in particular when we know that these countries have the oldest car fleets in Europe and that they are the most important net contributors to the growth of CO_2 emissions from cars in Europe.

Developing these markets would also allow a reconnection between their domestic automotive industries and the domestic markets themselves, putting an end to the 'race to the bottom' in working and employment conditions orchestrated by the constant competition between different high and low wage factories for the same products. It would also provide opportunities for real functional and social upgrading in these industries where new products for such new markets could ultimately be conceived, developed and manufactured.

To conclude, we have shown how the regulatory upmarket drift of the last twenty years has resulted in a process of rapid electrification that will be disruptive for the European industry and could even jeopardise EU Green Deal objectives. But we have also argued that combining electrification with a regulatory downmarket drift could open up much more sustainable scenarios for the future of the industry and for the capacity of the European Union to achieve carbon neutrality in 2050. The European level is decisive here and we call for ambitious, but also new and different, regulations and policies from those that have led us to these difficult choices.

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Chapter 2
Emerging battery value chains in Europe

Wolfgang Schade, Ines Haug and Daniel Berthold

Introduction

With the policy framework unfolding over the last ten years and being put into place for the next ten to twenty, the transition to electromobility has become inevitable. Examples of such a framework are:

– The European Commission in July 2021 put forward the ‘Fit for 55’ package of legislative proposals including setting a -100 per cent CO_2 standard for new cars by 2035. This implies that all sales of cars in the EU would have to be either battery electric vehicles (BEV) or fuel cell electric vehicles (FCEV) (EC COM(2021) 556).
– Over the past three to five years automakers themselves have continuously raised their ambitions concerning the share of electric car sales they are planning for in 2030. Across the board the range is between 70 per cent and 100 per cent.

So, there is no question about the ‘if’, the question is only about ‘how’ to cope with the transition to electromobility. This chapter sheds light on the case of battery production, one pillar of the transition, which is of particular importance for the future of the European automotive industry. It thus focuses on battery cell production in Europe, analyses the status quo and outlines the future developments that can be expected up to 2030. It is thereby limited to lithium-ion batteries for automotive applications, as that is seen to be the dominant technology in the next decade.

Section 1 outlines the status and development of battery technology and the battery value chain, while Section 2 addresses battery production in Europe and the strategies of European original equipment manufacturers (OEMs). Section 3 analyses the cost structure of cars, comparing battery electric (BEV) and internal combustion engine (ICE) vehicles, Section 4 adds an innovation system analysis while Section 5 looks at the employment effects. Section 6 evaluates what is at stake for the European automobile industry and Section 7 concludes.

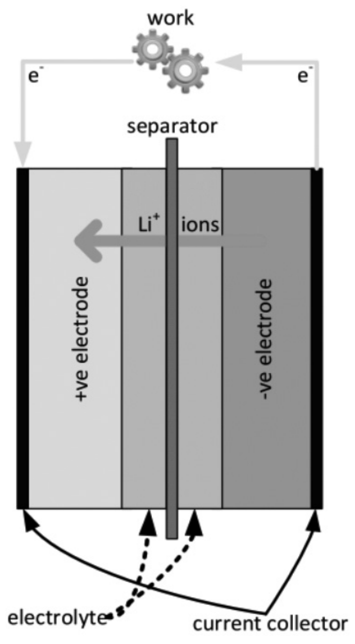
1. Status and development of battery technology and the battery value chain

This chapters focuses on lithium-based batteries as this technology has been identified to be the dominant technology until 2030 (Zubi et al 2018). This section does not claim to provide a complete consideration of all technical specifications but is rather intended to lay the foundation for a subsequent evaluation of the European battery cell manufacturing industry.[1] As there are currently different types of lithium-ion (Li-ion) battery cells used in BEV, it is not only important that Europe is able to build up its own local battery cell production but also whether it relies on the right technology and can serve global demand. Therefore, the assessment of competitiveness is preceded by a brief technical consideration.

1.1 Status quo of Li-ion battery technology

Figure 1 presents the construction of a Li-ion battery, including the positive and negative electrode, the electrolyte, the separator and two current collectors. During discharging, lithium ions, Li+, flow from the negative electrode (the anode) through the electrolyte to the positive electrode (the cathode). The separator allows the flow of lithium ions between the two electrodes while blocking the flow of electrons within the battery. During charging, the flow is reversed (Miao et al. 2019).

Figure 1 **Li-ion battery construction**



Source: Miao et al. 2019.

An analysis of the recent scientific and industrial literature on Li-ion battery technology identifies the composition of the cathode as the most important differentiating factor. The most commonly used cathode materials in vehicle applications are lithium iron phosphate (LFP), lithium nickel cobalt aluminium oxide (NCA) and lithium nickel

1. We do not discuss the potential of non lithium-ion technologies, such as sodium-ion battery technology, which are being researched but whose market entry is highly uncertain before 2030 (Schwarzer 2021).

manganese cobalt oxide (NMC). Lithium titanium oxide (LTO) and graphite represent the common anode materials in Li-ion batteries. Graphite remains the material of choice due to its high energy density, abundance and low cost (Miao et al. 2019). Table 1 provides an overview of the most commonly used cathode materials in Li-ion batteries in use for electric vehicles and their respective characteristics.

Table 1 **Overview of status quo Li-ion battery technology for electric vehicles**

Cathode	LFP [$LiFePO_4$]	NCA [$LiNiCoAlO_2$]	NMC* [$LiNiMnCoO_2$]
Anode	Graphite	Graphite	Graphite, LTO
Specific energy [Wh/Kg]**	90-190	200-270	150-270
Full cycles	2000	1000-1500	1000-2000
Safety	Very high	Low to Medium	Medium to High
Cost	Low	Medium	Medium
Further advantages	Eco-friendly materials (cobalt free)		Tailored solutions through varying proportions of nickel, manganese and cobalt
Applications	Electric vehicles, e-bike, projections for power supply systems	Electric vehicles, projections for grid connected use	Electric vehicles, PHEV, portable electronics, power tools, medical devices
Electric vehicle application	Minor interest so far	Minor interest mainly from Tesla	Dominant application

* The characteristics depend on the individual ratio between nickel, manganese and cobalt.
** Specific energy is an indicator of how much energy a battery contains per kilo of weight; it is considered at cell level throughout this chapter.
Source: M-Five own illustration based on Zubi et al. 2018, Marscheider-Weidemann et al. 2021, Miao et al. 2019 and Lima 2020a.

There is no universally favoured technology to date. With regard to applications in BEV, the specific energy affects the range per charge. The number of full cycles indicates after how many cycles the performance of the battery drops to 80 per cent of its original value. Safety refers to the thermal stability of chemicals; that is, their decomposition at higher temperatures. Costs are largely determined by the raw materials used which is why low-cobalt compositions show a cost advantage. With high specific energy, long life and moderate to high safety at moderate cost, NMC is the predominant application. NCA shows high specific energy at moderate cost, but lower lifetime and safety compared to NMC. LFP shows the advantages of long life, very high safety and low cost, but suffers from lower specific energy, thus making it of minor importance for automotive applications so far. In general, the cathode composition affects the specific energy, cost and sustainability of a battery; the anode affects the charging performance (Volkswagen AG 2021).

LFP, NCA and NMC cathodes as the dominant solution for battery electric vehicles

For the dominant NMC cathode, the composition of nickel, manganese and cobalt can vary in different specifications. Today, in addition to the original NMC111, manufacturers are also making NMC622 and NMC811, with the three digits referring to the proportions of nickel, manganese and cobalt (Batteries Europe 2020). Over time, development has moved from equal composition from the three materials towards more nickel content (i.e. from NMC111 to NMC622). The increase in nickel at the expense of manganese and cobalt results overall in higher specific energy and lower cost: nickel is considered the key to high energy but suffers from low stability; manganese adds high thermal stability; while cobalt is considered the most expensive and toxic material to eliminate (Ding et al. 2019).[2] The reduction in cobalt content is confirmed by analysis by Agora Verkehrswende (2021a), which examined 147 BEV models introduced to the German automotive market between 2017 and 2021. While NMC111 and NMC532 dominated in 2017, NMC622 was most popular in 2018, 2019 and 2020 while, for 2021, NMC811 was expected to become dominant in BEV model launches.

In addition, there is already extensive research on cobalt-free cathodes known as NMX. In July 2021, the Chinese battery manufacturer Svolt announced the start of its series production of NMX cells which are composed of 75 per cent nickel and 25 per cent manganese (SVOLT 2021). The absence of cobalt and the reduction in nickel makes these cells both sustainable and cheap. A further recent development is the announcement by the German cathode manufacturer BASF of the production before the end of 2021 of NMC271 cathodes with high manganese content (Lima 2020b). This indicates that, after reducing the cobalt content, the next step is to reduce the nickel content which will allow a further price reduction, comparable to LFP. This change in composition is the result of a lively discussion about rare and thus expensive and critical raw materials, security of supply and fair working conditions.

NMC as the most commonly used cathode; LFP as promising parallel application

Tesla announced at its Battery Day 2020 that it will take a diversified cathode approach in future, including LFP cathodes due to their low cost, high availability and long cycle life advantages. Nickel and manganese-rich cathodes are being reserved for long-range vehicles and high-nickel cathodes for mass-sensitive applications (Tesla 2020). Similarly, Volkswagen announced at its Power Day 2021 that it will use LFP cathodes for entry-level vehicles, high manganese cathodes for the volume segment and NMC cathodes for specific solutions (Volkswagen AG 2021). A similar strategy is being pursued by Daimler (Schaal 2021a). Among battery producers, the Chinese companies CATL and Gotion High Tech in particular are focusing on LFP cathodes and are continuously raising their performance: CATL reports a 20 per cent price reduction compared to NMC811; while Gotion High Tech is significantly decreasing the gap in specific energy between LFP and NMC cells (Marklines Database). Overall, continuous improvement in the performance of LFP cells and a stronger focus on the availability of scarce and expensive raw materials are leading to the increased importance and awareness of LFP technology.

2. In the case of NCA cathodes, a further distinction can be made between NCA15 and the newer NCA5. Again, the trend is towards a reduction in the cobalt content (Marscheider-Weidemann et al. 2021).

The producer side (not only for LFP, but for Li-ion battery cells in general) is currently strongly dominated by Asian companies, which were the first to enter the market in Li-ion battery cells and which started to develop competences in this area as early as the 1990s. Whether European companies will be able to catch up and achieve technological leadership as well as significant market shares is discussed in Section 3.

Box 1 **Greenhouse gas emissions by Li-ion battery technology production**

In a recently published study, the International Council on Clean Transportation (ICCT 2021a) analyses the life cycle GHG emissions of batteries, considering NMC111, NMC622, NMC811, NCA and LFP cathodes in combination with a graphite anode and the production regions of Europe, USA, China, South Korea and Japan. GHG emissions considered in the vehicle cycle consist of the production of the battery pack including upstream raw material extraction and processing, cell production and pack assembly. In addition, regionally and temporally adjusted carbon intensities and battery capacities are considered. Secondary use or recycling of the batteries is not taken into account as it is of minor relevance so far (which will change in the future; see Section 3). The study shows that the carbon intensity varies depending on the battery chemistry. For Europe, the lowest kg CO_2 equivalents per kWh are generated by the production of the LFP graphite composition: 34 to 39 kg CO_2 equivalents per kWh. In descending order, NMC811 (53 kg), NMC622 (54 kg), NMC111 (56 kg) and NCA (57 kg) follow. In a comparison with the main producer countries, European production has the lowest GHG emissions (ICCT 2021a).

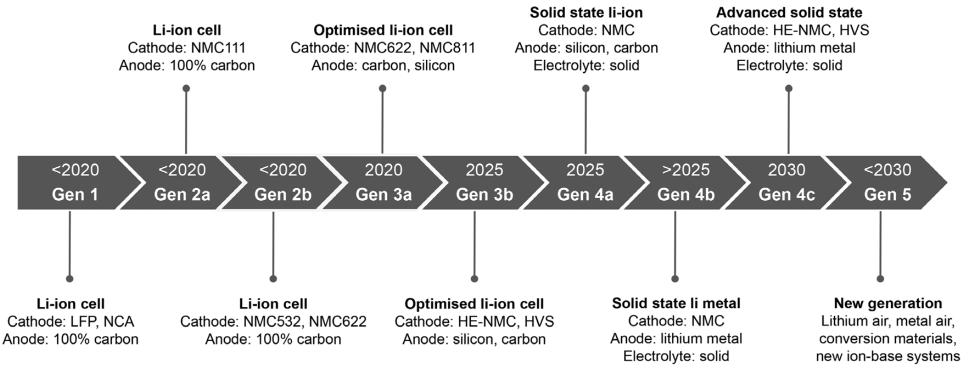
1.2 Development of battery technology until 2030

Following this general consideration of Li-ion battery technology, this subsection provides an outlook on expected future developments up to 2030. Different materials for cathode, anode, electrolyte and separator are able to improve the battery further, making it cheaper, lighter and more powerful.

The literature consistently divides technological developments into five major generations as well as sub-generations. These are shown in Figure 2 and thus provide a comprehensive overview of past and future expected developments in Li-ion battery cell technology. HE-NMC refers to high-energy NMC composition; HVS to high-voltage spinel.

An estimate by Marscheider-Weidemann et al. (2021) confirms Generation 2b with NMC622 as the current state of the art in the automotive industry, while Generation 3a with NMC811 is in the process of commercialisation.

Figure 2 **Categorisation of Li-ion batteries**



Source: M-Five own illustration based on Batteries Europe 2020.

Generation 2b as current state of the art; generation 3a in the process of commercialisation

With the beginning of the third generation, the optimised lithium-ion cell, the composition of the anode changes. Part of the graphite is replaced by silicon, which is the most promising anode material for achieving high performance due to its high theoretical capacity. However, challenges such as volume expansion during discharging and charging must be overcome before implementation (Zhao and Lehto 2020).

The fourth generation is characterised by the introduction of a solid electrolyte, leading to the so-called solid-state battery in which the flammable liquid electrolyte is replaced by a solid electrolyte that acts as an ionic transport support and separator. As a result, these batteries have the advantages of increased safety, durability, energy density and a reduction in volume, among others (Ding et al. 2019). However, only with the introduction of the lithium metal anode can the full potential of solid electrolytes be exploited.

With generation five, expected after 2030, a move away from Li-ion batteries towards lithium-air or lithium-sulphur is expected as Li-ion batteries will have reached their natural limit in specific energy while new batteries with higher specific energy will reach market maturity (Ding et al. 2019).

As already mentioned, production is strongly dominated by Asian companies at present. The introduction of new generation technologies is the subject of extensive research and development activities which are also taking place in Europe and offer an opportunity to gain market share, capture value in Europe and contribute to provide high-skilled employment. However, competitors are also active in this field.

To gain further insight into the expected major developments up to 2030, a roadmap analysis has been conducted. Roadmaps highlight long term strategic and technological development and serve as a guideline for future technology development. A large number of roadmaps on Li-ion batteries already exist but differ in their focus and design. Both industry and academia roadmaps are considered; moreover, combined roadmaps have been developed, providing shared expertise. In general, industry roadmaps tend to contain quantitative outcomes and key performance indicators while academic roadmaps take a qualitative perspective. The presence of a large number of industry roadmaps in addition to academic ones suggests that it is no longer a pure research topic but already the subject of practical implementation.

The previous analysis focused on the materials used, so the following short roadmap analysis is a complement to Table 1 in focusing on selected characteristics such as specific energy, full cycles, safety and cost. Table 2 compares and subsequently evaluates two selected roadmaps (by 2025 and 2030) with regard to the development of battery technology for BEV today, considering a European perspective and focus on Li-ion batteries.

Table 2 **Analysis of battery roadmaps**

Roadmap	Status quo	Expected development by 2025	Expected development by 2030
• "Battery Innovation Roadmap 2030" • EUROBAT (2020) • Association of European automotive and industrial battery manufacturers • *Industry*	• Cathode: NMC111, NMC532, NMC622, LFP, LMO, LCO and NCA (Gen 2a, 2b) • Anode: C, LTO (Gen 2a, 2b) • Specific energy: 250 Wh/kg • Full cycles: >3500 • Recycling efficiency: 50%	• Reduced cobalt content with increased nickel content in the cathode • Carbon and silicon as high capacity material in the anode • Focus on range, fast charging, safety and cost	• Cathode: NMC622, NMC811, HE-NMC, HVS, solid-state (Gen 3a, 3b, 4a) • Anode: C + Si, Si + C (Gen 3°, 3b) • Specific energy: 450 Wh/kg • Full cycles: >10 000 • Recycling efficiency: 80-85%
• "Strategic Research Agenda batteries" • Batteries Europe (2020) • European Technology and Innovation Platform on Batteries (ETIP) • *Industry & academia*	• Gen 3b with liquid electrolyte • Specific energy: 250 Wh/kg • Full cycles: 1000 • Cost per cell: 125 euros/kWh • Recycling efficiency: cobalt and nickel = 50%, copper = 90%, lithium = 35%	• Gen 4a with solid electrolyte	• Gen 4b, 4c with solid electrolyte and lithium anode • Specific energy: 450 Wh/kg • Full cycles: 2000 • Cost per cell: 70 euros/kWh • Recycling efficiency: cobalt and nickel = 60%, copper = 95%, lithium = 75%

Source: M-Five own illustration.

Major developments expected in specific energy, full cycles, cost and recycling

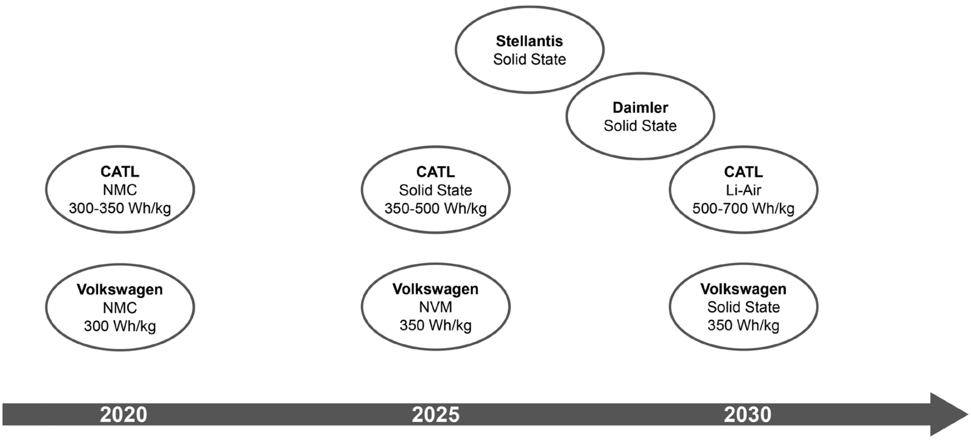
Major changes are expected in the characteristics of specific energy (determining the range), full cycles (determining the lifetime), cost and recycling. The lower limit for specific energy in 2030 is up to 320 Wh/kg; the upper limit assumes about 450 Wh/kg which is almost a doubling compared to the status quo. The number of full cycles should be viewed with caution in terms of application as it differs for automotive application and (second life) stationary applications.

The first roadmap highlighted in Table 2, from EUROBAT, considers Li-ion batteries in general; the second, from Batteries Europe, refers to automotive applications in particular. Li-ion batteries in electric vehicles achieve 1000 cycles today and will reach 2000 by 2030 (Armand et al. 2020), while in stationary applications they achieve 5000 cycles today and 10 000 by 2030. With an estimated average range of, currently, about 350 km and 1000 full cycles, 350 000 kilometres are feasible. Both parameters are expected to increase significantly by 2030. The cost per cell and pack will reduce while recycling rates will increase by 2030.

Overall, the development of battery technology until 2030 consists of changes in materials for cathode, anode, electrolyte and separator and thus improved performance characteristics such as specific energy and full cycles. Decreasing costs will open up the mass market, while increasing recycling rates will strengthen the security of supply and sustainability of the battery.

Lastly, announcements of technology developments by European OEMs and global battery producers are considered. An overview of activity drawn from press releases is shown in Figure 3, although many companies do not publish such performance indicators.

Figure 3 **Timeline of announced Li-ion battery generations**



Source: M-Five own illustration based on press releases.

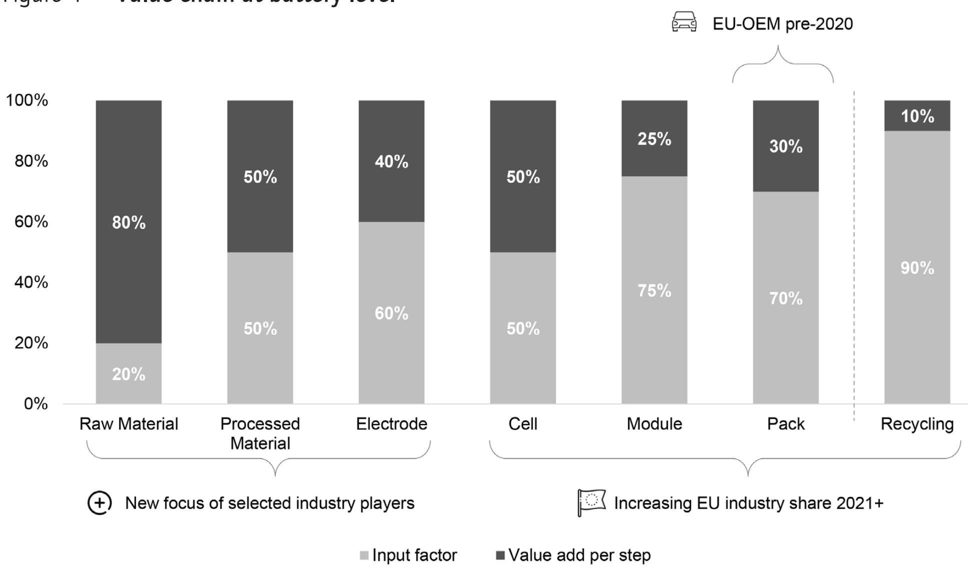
By 2020, Volkswagen is seeking to deliver NMC811 cathodes with an anode containing 80 per cent graphite and 20 per cent silicon, reaching a specific energy of 300 Wh/kg. By 2025, with a nickel vanadium manganese cathode and a combined graphite and silicon anode, 350 Wh/kg is expected. By 2030, the solid-state battery will have been introduced, offering the advantages of increased safety, durability and energy density. Stellantis and Daimler expect their solid-state battery by 2026 and 2028, respectively. On the producer side, CATL expects to deliver its solid-state battery by 2025 with a high voltage cathode and a lithium metal anode, reaching 350 to 500 Wh/kg. By 2030, CATL is expecting lithium-air batteries with a major increase in specific energy of up to 800 Wh/kg.

The technological leadership of CATL also underlines the current lead of Asian manufacturers in general. The technology shift to the fourth generation of Li-ion batteries, the solid-state battery, is associated with major challenges and a high level of expertise. As a result, various strategic partnerships and investments can be observed. While European manufacturers are now entering the market and catching up on current technologies, the introduction of the fourth generation of Li-ion battery enables European players to join this market from the very beginning and gain significant market share. The next generation of Li-ion battery technology is seen as a great opportunity to compete with Asian manufacturers from the outset and is therefore already in focus.

1.3 Cost and value chain at battery level

The production of a Li-ion battery can be divided into sequential activities, each consuming resources and creating value. Figure 4 depicts the Li-ion battery value chain for automotive applications. The European Commission assumes by 2025 a market value for the European battery value chain of 250 billion euros (European Commission 2020a). Given this magnitude, it is not surprising that OEMs are starting to focus on expanding and integrating further parts of the value chain, primarily upstream integration. In addition to this value chain, there are also upstream and downstream industries, such as mechanical and plant engineering, closely linked to battery cell production and the creation of additional value for Europe.

Figure 4 **Value chain at battery level**



Source: M-Five own illustration based on Sharova et al. 2020.

Figure 4 shows a highly simplified representation of the value chain, considering only one input factor and one output factor at each step. It shows the value added per activity at each step on top of its specific input factor. In the last step of manufacturing, the pack, the input factor accounts for 70 per cent of the revenue while the value added at this step represents 30 per cent of the revenue. Each step includes the previous steps as input factors. Before 2020, European OEMs focused only on pack integration. Since 2021, cell and module are increasingly in focus, as cell manufacturing in particular is a high value contributor. In addition, the upstream integration of raw and processed materials is also becoming important as it is increasingly clear that bottlenecks will occur at these stages while securing access and gaining control over this part is crucial.

Recycling is not yet fully integrated into the value chain. However, it will be an important aspect in the future from the point of view of raw material supply, environmental friendliness and user acceptance, as well as the development of a competitive European battery cell industry. In the future, value creation is expected to shift from modules and packs as well as integration to raw materials and their processing (CLEPA 2021). The reasons are the increasing automation and scaling of cell production, the decreasing importance of modules as a separate component and the increasing importance of raw material supply and cell chemistry.

Raw materials are the very beginning of the production process and represent high value add. Regarding the different types of Li-ion batteries, the main raw material requirements include lithium, nickel, manganese, cobalt and graphite. A comparison by Marscheider-Weidemann et al. (2021) of global raw material production in 2018, with a view to the raw material demand for Li-ion batteries in that year, shows that lithium and cobalt account for the highest shares of production today, each with a share of 8 per cent of production. The demand estimated by the sustainable scenario 2040 exceeds the 2018 production for lithium and cobalt while production for nickel, manganese and graphite would be sufficient. The greatest increase in demand is expected for lithium and nickel since the latter is being chosen to substitute for scarce and expensive cobalt in NMC cathodes. In the IEA's 'Stated Policies' scenario, lithium demand increases 12-fold from 2020 to 2040; and even 43-fold, to 859 kilotonnes (kt), in its 'Sustainable Development' scenario. Nickel increases 12-fold and 41-fold respectively, to 3287 kt in 2040.

However, such future projections are subject to large uncertainties due to the development of future battery cell chemistries. The increase in overall demand for Li-ion batteries can be partially offset by the use of less lithium-intensive cathode chemistries. The growing demand for raw materials due to the increased ramping-up of electromobility is leading to more intensive discussions about potentially critical raw materials and security of supply in Europe. There is an important difference between the general availability of raw materials on earth and the current extraction possibilities. While overall an adequate supply of raw materials is assumed, temporary shortages and price increases are expected due to the extremely long and bureaucratic opening time for new production facilities (Fraunhofer ISI 2020; NPM 2021).

Lithium, cobalt, nickel and graphite as critical raw materials

European OEMs have no core competence in raw material extraction and thus depend on mining and refining companies abroad.[3] Overall, the extraction of raw material is often geographically localised and oligopolised, with Europe using its resources only to a limited extent and being heavily dependent on imports (Sharova et al. 2020). Lithium is concentrated in Australia and Chile; cobalt in the Democratic Republic of the Congo; nickel in Indonesia; and graphite in China. It is worth noting that mining for these materials does, in some countries, involve regimes not averse to using child labour, the impact on workers' health and safety, etc.

The processing of these minerals is highly concentrated in China (IEA 2021). A secure value chain and sufficient access to raw material provides the main challenges of the future, a point which is emphasised by high price volatility.

One possible strategy could be upstream integration up to raw material extraction, for example in Europe, as well as the development of recycling capacities in the sense of developing the circular economy.

The next step in the value chain is material processing which is closely linked to raw material extraction. In order to secure supply, exploit cost potentials and develop individual technological advantages, the trend is towards reducing the content of critical raw materials and integrating the upstream value chain. As demand increases, cell manufacturers are opening new production sites close to potential customers (Sharova et al. 2020).

The battery cell, the fourth step in the chain, is manufactured by placing the cathode, the anode, the separator and the electrolyte in an aluminium case. Due to their experience in consumer electronics and initial automotive projects, Asian companies currently dominate this step (Sharova et al. 2020). A battery cell forms the basic unit of a Li-ion battery, with multiple cells being combined into a frame that builds the battery module. Multiple modules form the battery pack which is installed into the electric vehicle (Samsung SDI 2017).

After reaching their end of life in BEV applications, used batteries can enter either the second last step in the value chain, the second life, or the last step, recycling. There is also a discussion on re-*x*, based on re-use, re-manufacture and re-cycle (Battery LAB 2021). Remanufacturing extends the first life by replacing or exchanging damaged components. Recycling is required to recover raw materials and thus enable security of supply and sustainability.

There is, to date, no standardised recycling process present, with no thorough economic process for cathode materials and no industrial recycling solution available for anode materials (Battery LAB 2021). However, the need for recycling has been recognised

3. European mining activities are about to start. Current projects and the emerging phenomenon of NIMBYism are discussed in Box 2.

both in politics and in industry; moreover, technical feasibility is a given. The absence of economic feasibility requires legislative support. The European Commission proposes material recovery rates of 90 per cent for cobalt and nickel in 2025, increasing to 95 per cent in 2030; and 35 per cent for lithium in 2025, increasing to 70 per cent in 2030 (European Commission 2020b).

Another important aspect that must not be neglected is the quality requirement ensuring that recycled materials flow back into the Li-ion battery value chain and preventing downcycling (Transport & Environment 2021b). However, a distinction must be made between material recovery rates and the mandatory minimum shares of recycled content in a battery, which are 12 per cent for cobalt, 4 per cent for lithium and 4 per cent for nickel from 2030; and 20 per cent for cobalt, 10 per cent for lithium and 12 per cent for nickel from 2035 (European Commission 2020b).

Recycling as an opportunity for European industry

The Li-ion battery recycling market is estimated at 1.5 billion dollars in 2019, 12.2 billion dollars in 2025 and 18.1 billion dollars in 2030 (Markets and Markets 2021). According to the latest announcements, the German cathode manufacturer BASF wants to push ahead with the recycling of nickel and cobalt, as these raw materials for batteries will not be available in sufficient quantities in the future and the focus clearly is on establishing a circular economy. The French Automotive Cell Company ACC even claims that recycling ‘will be the new “mine”’ (Witsch 2021b). In general, recycling is expected to increase with the rising demand for Li-ion batteries, stricter regulations and volatile and rising raw material prices. The contribution of recycling to raw material demand is, however, only estimated at 40 per cent for cobalt and 15 per cent for lithium, nickel and copper in Europe by 2040 (Fraunhofer ISI 2021).

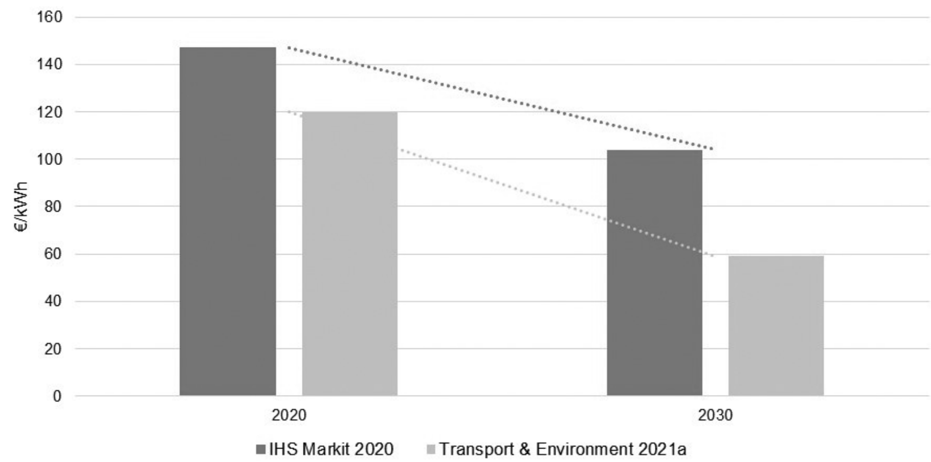
The value of recoverable material for a standard 70 kWh battery is estimated at 600 euros for LFP and 1300 euros for NMC cells. This shows the opportunity for Europe to develop a valuable market for battery raw materials, establish a local circular economy and thus strengthen the entire European industrial system. At the same time, it shows that the recovery of iron in LFP cathodes is not economically viable and requires legislative support if green batteries are preferred.

So far, seventeen recycling plants with a total capacity of 33 kt per year have been announced within Europe. These are mainly pilot plants that initially recycle production waste in addition to the batteries. Although established Asian companies have so far held a leading position in recycling, it is assumed that Europe, as the dominant market for environmentally friendly and highly efficient battery recycling, could meaningfully replace them (Fraunhofer ISI 2021).

1.4 Cost at cell level

This subsection addresses cost developments in Li-ion battery cells. Cell costs are often referred to in terms of the pack prices charged to manufacturers. Overall, the price per kWh has fallen significantly and this trend is expected to continue in the future. The main drivers are the increase in the volume of production, new pack designs, new cathode chemistries and falling manufacturing costs (Transport & Environment 2021a). However, volatility in raw material costs could counteract these trends and may increase pack prices in the future.

Figure 5 **Expected battery pack price in euros/kWh (nominal)**



Source: M-Five own illustration.

Figure 5 shows estimated prices for battery packs in euros/kWh from 2020 to 2030. While IHS Markit (2020) expects a rather small price reduction to 104 euros/kWh in 2030, Transport & Environment (2021a) provides a lower figure of 59 euros/kWh in 2030.[4] The range between the two shows that prices are influenced by various factors such as chemistry, volumes and negotiations and thus differ.

In general, up to 2020, it was economies of scale and learning effects as well as minor improvements in cell chemistry that drove this drop in prices. By 2030, however, fundamental improvements in cell chemistry are expected which can lead to significant performance improvements and even greater cost and price reductions. Nevertheless, the cost of lithium carbonate increased by 72 per cent, lithium hydroxide by 47 per cent and cobalt by 58 per cent in the first quarter of 2021 (Transport & Environment 2021a). These increases emphasise both the volatility of raw material costs and the relevance of cathode chemistry as the cathode contains active materials that are the most cost sensitive. The future development of the cathode is not only aimed at increasing the specific energy, but also at switching to abundant, cheap, price-stable, environmentally friendly and risk-free raw materials.

4. Personal communication with Chinese experts reveal a Chinese cost target for cells of 30 dollars/kWh in 2030. At such cell costs, the price of battery packs may well stay below even the lower pack prices anticipated by T&E.

By 2020, the battery was accounting for about 30 to 40 per cent of the total cost of a BEV (Sharova et al. 2020). The cell accounts for about 75 per cent of the price of the pack (Transport & Environment 2021a). The cell, the basic unit of the battery, can be further divided into its individual components: the cathode represents about 32 per cent of the cost and takes the largest share, followed by the anode (22 per cent) and the separator (14 per cent).

The costs at cell level can also be broken down differently: 65 per cent are attributable to material costs, 20 per cent to production costs and 15 per cent to distribution, administration and general costs as well as profit (Stanek and Hackmann 2020). The high share of material costs underlines the importance of cheap and available raw materials to facilitate the expected developments with regard to future price reductions.

1.5 Cost structure of cars

Section 2.4 on the cost at cell level has shown that battery costs are expected to decrease in the coming years. This decrease is expected to be accompanied by a reduction in the pre-tax selling price of BEV in general. In addition to falling battery costs, the switch to dedicated platforms for BEV and higher production volumes are further driving this development.

There are four main characteristics identified as determining the pre-tax retail price of a BEV. First, platform choice; second, battery price; third, driving range; and fourth, vehicle efficiency (Transport & Environment 2021a). The cost difference between ICEV and BEV today varies with the size of car and is the highest for the small A and B segments of the market. By 2024 to 2026, price equality is expected in all segments, first of all in light vans and lastly in the B segment.

Regarding cost structure, it has to be considered that, while prices for BEV are declining, prices for ICEVs could potentially increase. The expenditure entailed by improving the combustion engine in line with stringent CO_2 emission regulations and the Euro 7 standards potentially entering into force by 2025 will, according to one study, increase ICE prices significantly (Transport & Environment 2021a). This study treats such an increase as a given but the effects of these regulations and standards are as yet unclear. If CO_2 standards, in particular by 2025, are not tightened, given the expected high market uptake of electric vehicles, the pressure to invest in efficiency gains for ICE remains very limited as the CO_2 standards can simply be fulfilled by electrification. Thus we would rather anticipate stable ICE prices than increasing ones.

The value structure of BEV can be analysed by looking at the individual components and their cost shares in manufacturing in isolation, similar to the component analysis in Section 5 on the employment effects. For BEV, the share of the battery manufacture cost is forecast to decrease, from 36 per cent in 2020 to 29 per cent in 2035. At the same time, the cost share of Advanced Driver Assistance Systems (ADAS) is increasing, from 4 per cent in 2020 to a forecasted 10 per cent in 2035. The highest cost share over time is calculated for the battery, followed by vehicle integration. In comparison with ICEV, the electric drive including the battery is more costly and reaches a higher share than the ICE and its powertrain. Also a study on sustainable mobility in Germany confirms the growing importance of electromobility components including the battery and of ADAS components (NPM 2021).

1.6 Outlook on future value chain adaptations

Recently, two new technologies have been discussed that would make parts of the value chain shown in Section 2.3 redundant: cell-to-pack; and cell-to-chassis. Cell-to-pack technology dispenses with the modules and integrates the cells directly into the battery pack. Cell-to-chassis dispenses with modules and packs altogether and integrates the battery cells directly into the chassis of electric cars. The latter technology is expected to be launched by CATL before 2030; the former is already in use (Schaal 2020). By eliminating modules and packs, more cells can be installed in the same space as the weight and volume of inactive materials are reduced, resulting in higher specific energy. According to CATL, the use of cell-to-pack technology can increase energy density by 15 per cent and reduce costs by 30 per cent (Marklines Database). LFP batteries in particular profit from this technology as they provide sufficient thermal stability and safety to be implemented without modules and thus compensate for their disadvantage in specific energy performance. CATL and BYD are currently pursuing this strategy.

Box 2 **European raw material supply**

The discussion on critical raw material supply in Section 2.3 and the increasing demand and production of Li-ion battery cells in Europe leads to rising interest in establishing an own, independent European raw material supply chain. Mining and refining are by now concentrated in only a few countries abroad and thus materials supply could pose a threat to the emerging industry in Europe. Lithium mining projects – such as the zero carbon lithium project by Vulcan Energy in the Upper Rhine Valley, the Project by CEZ group and European Metals in the Czech Republic and the Wolfsberg project by European Lithium in Austria – are currently coming into focus (Mining Editor 2022). The advantages of such projects are in the possibility of a completely localised and independent European value chain and the preservation and development of employment and value creation in Europe. In addition, the unique selling point of European-made batteries could be environmentally friendly, sustainable batteries for which the EU is currently developing a battery passport and which could best be guaranteed by European raw materials extraction.

On the other hand, there is strong opposition observed among the population to projects of this kind, with concerns about deforestation, dust, noise and environmental pollution. Local resistance can be observed for example at the Jadar Valley in Serbia, in Covas do Barosso in Portugal or in Caceres in Spain. Whether the local supply of raw materials is necessary or is optional for a successful European battery cell production needs to be evaluated by further research.

2. Battery production in Europe and the strategies of European OEMs

After the technical foundation was laid in Section 2 on the status and development of battery technology and the battery value chain, Section 3 presents the results of a location analysis for battery cell production plants and a comparison with the location decisions that have been made in practice.

2.1 Location decisions for battery cell production

The location matrix in Figure 6 shows an evaluation of twelve European and four non-European countries based on the framework conditions that are considered relevant for the establishment of battery cell production plants. The selected European countries play an important role in the European automotive industry today, or will do so in the future, and thus already fulfil a basic requirement. To enable a global comparison, the world's major players in battery technology – the USA, South Korea, China and Japan – are included in the analysis. Thus, attractive and expected locations for battery cell manufacturing in Europe may be identified. Ten indices describe the attractiveness of the country, with each index potentially consisting of several individual values. In order to reflect the importance of the individual index for location decisions, a weighting is applied.

The idea, the selection of the indices and the chosen weighting are based on a reference project of the National Platform for electromobility from 2016 (NPE 2016). This chapter updates and adjusts the data to provide more accurate and up-to-date results on the competitiveness of Europe as a location. The matrix is to be understood as a relative consideration of the countries in comparison with each other. The scores from one to five are calculated by dividing into quartiles the results across all the countries considered and then awarding one point if the respective country's score is below the first quartile and five points if it is above the fourth quartile. A value of five thus corresponds to the highest score. The final score is then calculated by multiplying the country's score for the respective index by the weighting in row two. The matrix is expanded to include the planned capacity in GWh for 2030 that has been announced so far.

Overall, the purpose of this location matrix is twofold. First, to provide a ranking on potential European locations where battery cell manufacturing could be located; and, second, to provide a global comparison of European countries in respect of the major players and global competitors.

Within Europe, Sweden and Norway show the highest overall scores. These countries offer cheap and green electricity in addition to a very attractive investment environment in general. However, the automotive industry is not present at all in Norway and is only rather limited in Sweden. This is matched by the announced production capacity in the mid to upper range. The highest planned production capacity in Europe is reported for Germany, which ranks third in the location matrix. In particular, the high level of vehicle production and the associated automotive technology infrastructure make

Germany an attractive location for further investment in this industry. With regard to planned capacity by 2030, Germany is followed by Italy, France and Hungary. In terms of rank, Germany is followed by Hungary, the Czech Republic, France and Spain in fourth place.

Figure 6 **Location matrix**

		Europe							
Index	**Weight**	**SE**	**NO**	**DE**	**HU**	**CZ**	**FR**	**ES**	**SI**
Labour	0,27	3	3	3	4	4	3	3	3
Energy	0,25	5	5	2	5	4	4	3	3
Logistics	0,08	4	3	5	1	2	3	3	1
Corporate tax	0,05	4	4	2	5	4	1	3	4
Country risk premium	0,05	5	5	5	1	4	4	2	3
Political stability	0,05	4	5	4	1	2	3	3	2
Transparency	0,03	5	4	4	1	2	3	3	2
Business attractiveness	0,05	4	5	4	3	2	4	3	3
Global innovation	0,07	5	3	4	1	2	3	2	2
Vehicle production	0,10	1	1	4	2	3	3	3	1
Score		**3,9**	**3,7**	**3,2**	**3,1**	**3,1**	**3,1**	**3,1**	**2,7**
Planned GWh 2030		60	75 +2	317 +3	88	0	94	10 +1	0

						Major Player			
Index	**Weight**	**PL**	**SK**	**RO**	**IT**	**US**	**KR**	**CN**	**JP**
Labour	0,27	4	3	4	3	4	4	4	3
Energy	0,25	3	3	3	2	4	3	3	2
Logistics	0,08	2	1	1	3	4	2	2	4
Corporate tax	0,05	4	4	5	2	3	3	3	2
Country risk premium	0,05	3	3	1	1	5	4	3	3
Political stability	0,05	1	2	1	2	3	4	1	3
Transparency	0,03	2	1	1	2	3	3	1	4
Business attractiveness	0,05	2	2	2	2	5	5	3	3
Global innovation	0,07	1	1	1	2	4	4	3	3
Vehicle production	0,10	2	2	1	2	4	3	5	4
Score		**2,6**	**2,6**	**2,5**	**2,4**	**4,1**	**3,5**	**3,2**	**2,9**
Planned GWh 2030		65	10	+1	110	288	32	1888	32

Source : M-Five, INACD.

Two large discrepancies between the calculated score and production capacity are visible in Figure 6. One is for the Czech Republic which, despite its high score, has not yet reported any production facilities; and the other is for Italy which scores the lowest but still has the second largest planned production capacity. The Czech Republic offers an attractive investment environment which is matched by negotiations being currently ongoing with two potential investors for a battery cell plant, one of which is VW according to the government (Reuters 2021). In Italy, on the other hand, there is a rather uncertain and unstable financial and political environment, as well as lower levels of automotive production. However, high levels of government support and funding are able to compensate for the uncertainty and lack of stability and the country has been able to attract two large cell plant investments from Itavolt and Stellantis (Schaal 2021b; Randall 2021a). The example of Italy shows the major importance of government support and subsidies. However, this support can be put into very different sectors of the economy and thus it cannot be integrated into the location matrix in general.

Another limitation of the matrix is that the indices measured today are compared with the production capacities expected for 2030. Today's location decisions take expectations about the future development of a location into account and this cannot be reflected in the matrix. In addition, there is no guarantee that today's announcements will be successfully operating at full capacity by 2030.

In a global comparison with the major players, the United States is in the lead followed by South Korea, China and Japan. The result of the United States also represents the highest overall score, while the results achieved by South Korea, China and Japan are equivalent to those of the European analysis. This indicates that the environment in Europe is competitive. Regarding the planned GWh capacity by 2030 of the four non-European countries, China shows by far the highest value followed by the United States, South Korea and then Japan.

A global ranking similar to the location matrix presented here has been conducted by BloombergNEF (2021) including the categories of (1) raw materials; (2) manufacturing; (3) environment; (4) regulations, innovation and infrastructure; and (5) battery demand. China ranks first according to the presence of major investments, control over raw materials and strong demand, both locally and globally. China is followed by the United States, Germany, Sweden and Canada. European countries appearing in the top 30 ranking are (in descending order) Germany, Sweden, Finland, Norway, France, the United Kingdom, Poland, Czech Republic, Hungary and Slovakia. This ranking underlines that European countries are competitive and becoming increasingly important in this industry, but supports also the view that R&D tends to be done within the 'core' of European automotive value chains. The development of the European battery cell industry is the subject of the following subsection.

2.2 European battery cell production

After the theoretical considerations, this subsection focuses on the announcements for European production made by the industry so far. M-Five maintains an Innovators and Actors Database (INACD) tracing the eco-system of mobility transformation and thus containing the players in automotive technology innovations as well as those offering new mobility services. INACD also includes the networks established between the players as well as the innovators and actors in the battery domain.

According to the INACD database, 25 plants are currently operating in Europe or have been announced, while six further plant announcements have been observed albeit without concrete information on production capacity. Total cell production capacity of 157 GWh has been announced by 2023 and up to 900 GWh by 2030. In almost all cases, production begins with a planned capacity lower than the maximum, with this then being expanded along the ramping-up curve of electromobility.

From the published information on planned production capacities and planned employees, an average figure of 58 employees per GWh across all production plants may be derived.[5] Applying this employment intensity to the 2030 capacity results in around 52 000 directly created jobs in the cell industry. Significant indirect job creation, both upstream in the supply chain and downstream in areas such as logistics, recycling, pack manufacturing and re-use are expected but have not been quantified in this research project.

A closer look at the announced production plants for battery cells reveals that both Asian and American manufacturers are pushing into the European market while European companies are building up their own local production capacities, thus increasing competition in the local market. According to our database, 50 per cent of the GWh production capacity by 2030 has been announced by companies based in Europe and the other half by companies based abroad. Both types of investment increase employment and financial capital in Europe and also strengthen the European battery innovation system (see Section 4). At the same time, employment creation within foreign-owned production may be limited to direct manufacturing jobs in Europe and local indirect employment, while many jobs such as R&D, management and marketing often remain in the home country. A major challenge for European companies is that, while foreign, established companies such as Tesla or CATL have already successfully set up several production facilities, many European companies are just entering the market and starting operations. They are more familiar with the market and regional conditions but have less experience at ramping-up cell production.

It should also be remembered that there are hurdles to scaling up and that not all announcements may actually be implemented.

Regarding the technological considerations outlined in Section 2, European manufacturers have so far focused on NMC high power and next generation solid-state cells. However, price seems to complement, or even replace, performance as the main criterion for cell selection. As a result, the focus is shifting from NMC to cheaper LFP cells since the latter have caught up in performance and now attain the minimum level required. Given the increasing demand for LFP cells for lower-end and entry-level vehicles, including from major European OEMs such as Volkswagen and the volume brands of Daimler, it will be an important decision whether this market should also be served by European manufacturers in the future or whether it will be left exclusively to Chinese companies. The Serbian company ElevenEs has taken a decision acknowledging the potential of LFP and recently announced that it will build the first LFP battery gigafactory in Europe, which is expected to start construction by 2024 and produce up to 16 GWh in the final expansion stage (Randall 2021b).

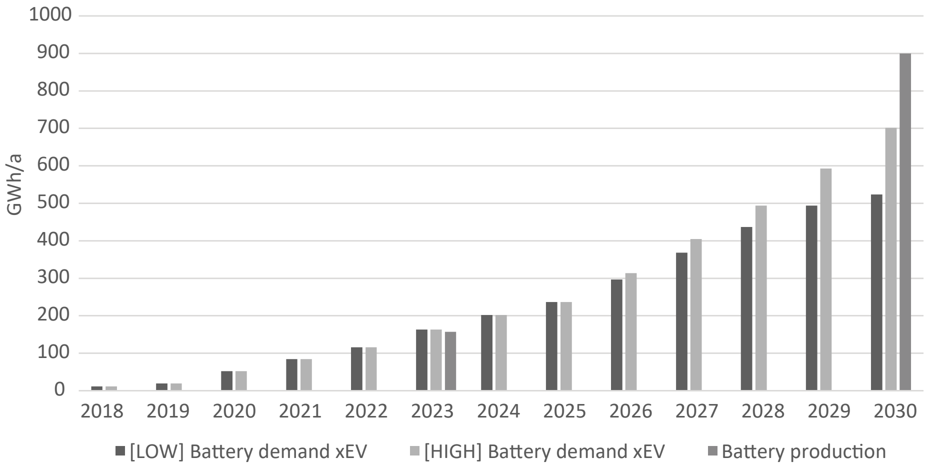
To complement the supply side, Figure 7 considers and compares the demand side for Europe. M-Five's estimate of European battery demand is divided into a low demand scenario and a high demand scenario to account for uncertainty in the expected market penetration of electric vehicles (passenger cars). Annual production data on

5. Excluding two outliers, the range of observed employment intensities of planned European battery cell manufacturing sites is between 21 and 98 employees per GWh. This shows both the variety of manufacturing plans and the uncertainty still associated with the plans.

the base of vehicle production sites is considered until 2021 (Marklines Database) and then projected until 2030. Following the rebound from the pandemic, the overall production level in Europe is assumed to remain slightly below the 2018 level until 2030. The share of electric vehicles (both BEV and PHEV) in overall car production is estimated at 28 per cent in 2025 in both scenarios; but 53 per cent in 2030 for the lower scenario and 71 per cent for the higher one.

Estimates for the lower scenario are in line with ICCT (2021b) projections to meet the average new car fleet CO_2 emission reduction of 50 per cent in 2030 (compared to 2021 levels). The estimates for the higher scenario are derived from our own calculations based on EEA CO_2 monitoring data from 2020 and our own assessment of EU countries according to their individual shares in electrification,[6] to meet an average new car fleet CO_2 emission reduction of 55 per cent compared to 2021 levels. The higher share of electric vehicles will lead to a higher demand for Li-ion battery cells. The share of BEV within electric vehicles is estimated at 82 per cent in 2030. Once electric powertrains become cost-competitive (which we expect in the mid-2020s), BEV will become increasingly attractive to car buyers. Battery capacities for BEV and PHEV are estimated at 75 kWh and 13 kWh each in 2030. This then leads to a lower demand of 524 GWh of battery cells for cars and an upper demand of 702 GWh in 2030 compared to the announced production of up to 900 GWh.

Figure 7 **European battery cell demand and production**



Source: M-Five own illustration and calculation.

Figure 7 shows that the increasing production capacity will be able to meet the increasing demand. For both scenarios, there is the possibility of over-capacity. This could be used to meet additional demand through the increased electrification of buses and trucks as well as to build up export capacities (for net car exports or direct battery

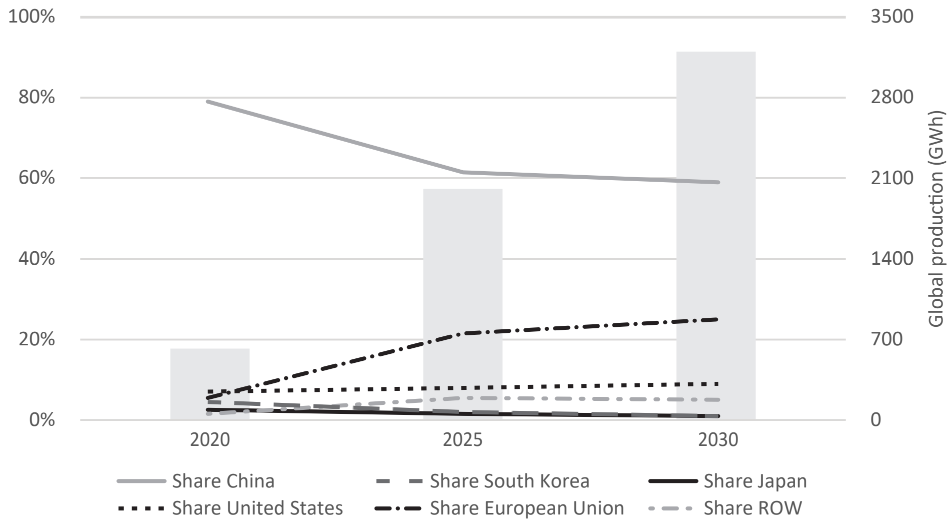
6. Denmark, Finland, France, Germany, the Netherlands and Sweden are classified as ambitious countries with a share of 89 per cent electric vehicles in new registrations in 2030.

exports). It is assumed that the European Union will be able to meet its own demand by 2025 and even build up an export capacity (European Commission 2020a). However, depending on the speed of electrification of buses and especially trucks, even more capacity might be needed as such applications require much larger batteries.

Projected European demand can be further broken down into regional demand. Based on current BEV sales, but also including the factors that influence these, such as GDP per capita and supporting policies, four groups can be identified. These are northern, western, southern and eastern Europe, with northern countries classified as innovators and early adopters; western countries as early majority; southern countries as late majority; and eastern countries as catching up (Transport & Environment 2021c).

In a global perspective, production volume is expected to be about 620 GWh in 2020, rising to 2008 GWh in 2025 and to 3200 GWh in 2030 (Transport & Environment 2021a; VDMA 2020). China accounts for the largest share, with around 80 per cent of production in 2020, and is able to keep its leadership until 2030. Europe is, however, increasing its share in global production at the expense of China. The other major production countries – the United States, Japan and South Korea – seem rather constant (Transport & Environment 2021a; VDMA 2020). Global battery cell production and the share of production capacity by country/region is illustrated in Figure 8.

Figure 8 **Global battery cell production and share of production by country**



Source: M-Five own illustration based on Transport & Environment 2021a; VDMA 2020.

One reason for this shift of production shares away from China and towards Europe is the proximity to target markets and OEMs. This proximity enables a reduction in transport costs which are non-negligible due to the weight and necessary safety factors in the transport of Li-ion batteries. It also increases security of supply, with the recent pandemic and the current chip crisis drawing attention to vulnerabilities in global supply chains. In addition, Europe's strength in mechanical and plant engineering is equally attractive to both Asian and European cell manufacturers (VDMA 2020).

While the highest battery demand by far is observed in China, the highest growth rate in demand is observed in Europe (World Economic Forum 2019). This leads to the assumption that Europe entered the market late but is now on the rise and both increasing its share of demand as well as of production.

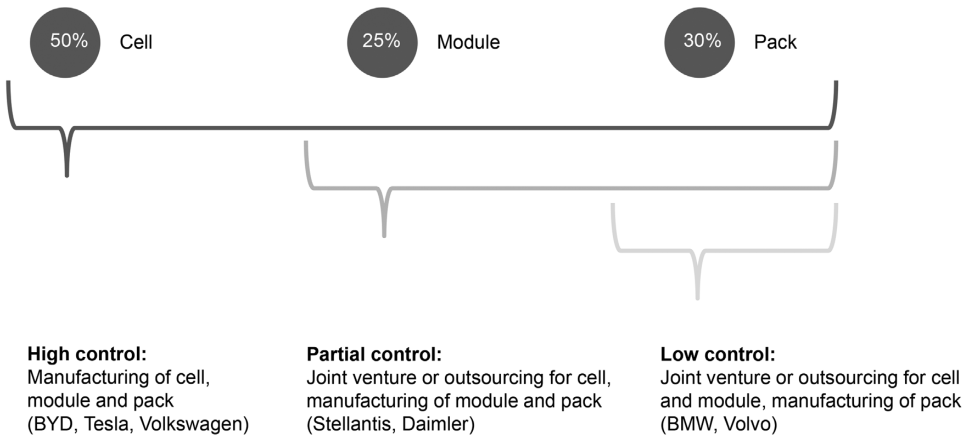
2.3 Different approaches to controlling the battery value chain

Different strategies are being pursued by European OEMs to capture and control shares of the battery value chain. At one extreme, a company may control the entire value chain from raw material extraction to pack integration. In the other case, a company might outsource all previous steps and focus only on vehicle integration. In between, partial control of the value chain is observed by entering into partnerships and joint ventures.

The focus of European OEMs over the last three years has shifted from pack integration to upstream cell production, not least due to the high value-added share of the cell in the overall battery but also due to the insight that BEV sales will increase sharply during the first half of the 2020s. In addition, this approach increases security of supply through localisation and the opportunity to form unique technological selling points. Furthermore, it enables the company to keep its employees, which is why upstream integration, for example in the production of battery cells, is also being pushed by works councils. As early as 2014, and following the discussions initiated in co-operation with a few council members by Bormann et al. (2014) at several German manufacturing sites, works councils have placed emphasis on participating in e-mobility developments or even transforming their sites into e-mobility powerhouses. Various strategic options along the value chain have emerged out of such a discussion. Figure 9 shows three main strategies and the companies pursuing them, making reference to the respective steps of the full value chain as explained in Section 2 (see Figure 4).

Among European OEMs, some companies with moderate to medium-size volumes of car sales, such as BMW or Volvo, find their dominant strategy in having low control of the value chain while focusing on vehicle integration. BMW recently announced that it feels vindicated for not entering the market as a battery cell manufacturer. There is a robust supplier market with no monopoly, oligopoly or bottlenecks. Moreover, the company is still able to define requirements and needs in its research centre and pass these on to its suppliers (Matthes and Fasse 2021). However, the head of the BMW works council is less satisfied with the strategy of the purely external procurement of battery cells, especially with regard to the associated employment effects (Wermke 2021). In contrast, Daimler recently announced it would join the ACC joint venture between Stellantis and TotalEnergies for European cell production. The company will develop and produce battery cells and modules in Europe while exploiting benefits such as ensuring security of supply, economies of scale and the ability to offer superior and tailored battery technologies. Moreover, this investment is expected to strengthen the competitive position of the whole European industry (Daimler 2021). Volkswagen is going one step further and has announced not only the planning of six European gigafactories with a total capacity of 240 GWh (Volkswagen AG 2021), but also the Intention to encompass the entire value chain in the future, from mining and refining to cathode production (Volkswagen AG 2019).

Figure 9 **Control of the value chain**



Source: M-Five own illustration based on Marklines Database.

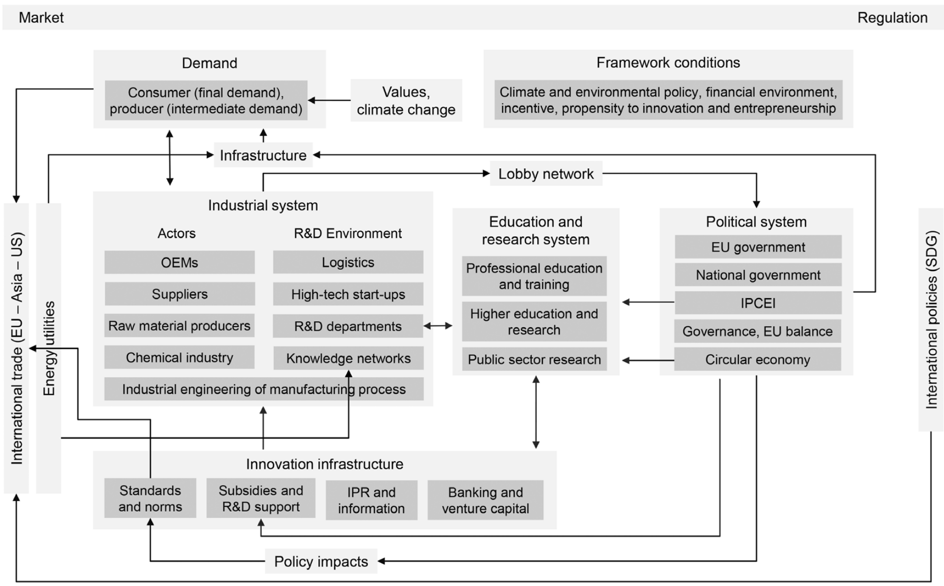
In general, we can identify the size and influence of the works council as one driver in OEMs choosing to set up their own battery cell production capacities. Negative employment effects are expected from the conversion of production from ICEV to BEV, so the demand for own battery cell production facilities close to established production sites may be expected to increase.

Another strategy that BYD is pursuing successfully, and for which Dyson was originally also aiming, is downstream integration in which battery manufacturers enter into vehicle production. However, Dyson had to discontinue its electric car project for economic reasons (Schaal 2019). The discussion about the integration of battery cell production into the OEM value chain eventually also leads to this value creation being taken away from powertrain-dependent suppliers. The shift to electromobility is therefore also accompanied by a shift in value creation, away from the supplier and towards the car manufacturer. Mercedes, for example, has announced that it will significantly increase the vertical range of manufacture for the next generation of electric cars and thus switch from outsourcing to in-house production (Gerster 2022). This development thus leads to a movement of jobs rather than a complete avoidance of job losses. The employment effects are considered in more detail in Section 5.

3. Innovation system analysis

Innovation system analysis originally researched the capability of nations to create and implement innovations (Arnold et al. 2001). The concept has been transferred to the sectoral analysis of the automotive industry and describes the interaction between markets, regulations and various types of interacting networks (Schade and Krail 2012). This chapter uses the concept to elaborate the technological innovation systems (TIS) of battery technology for vehicles (see Figure 10). Overall it reveals that Europe offers a very attractive, and in many adjacent areas already successfully operating, environment for the production of battery cells.

Figure 10 **Technological innovation system analysis of battery cell manufacturing**



Source: M-Five own illustration.

The development of innovations is framed by their environment with the market (including domestic and international) on the one side and, on the other, regulation reflecting national and international policy objectives. In the case of battery manufacture, such framework objectives include European climate targets but also green growth objectives as electric vehicles and their batteries may constitute an element of green growth.

Several elements of the political system directly address the achievement of European battery innovations; that is, the classification of battery manufacturing as an Important Project of Common European Interest (IPCEI) and the provisions for establishing a circular economy in Europe which support the establishment of a European resource base for batteries via an emphasis on the need to establish a battery recycling industry.

These elements stimulate the education and research system to direct its efforts towards battery related innovations (e.g. materials science, recycling, production processes) and thus support the industrial system and its various R&D departments by developing new technologies and manufacturing processes for vehicle batteries.

Looking at two of the parts of the wider innovation system – that is, the political system and the education and research system – political efforts (guidelines, financing and research capacities) have, in recent years, led to the development of viable and effective system elements in Europe which are capable of supporting a potentially successful European-level innovation in battery technology.

The industrial system needs to establish and improve the networks between OEMs and their suppliers: the chemical industry to provide the materials for the battery (e.g. anode, cathode) in the right quality; the machine engineering sector to develop the production machines and plants for the batteries; and the logistics sector as lithium batteries do, at some stage of their production, have to be handled and transported as a regulated dangerous good. Together with the start-up scene within Europe or outside Europe but in connection with European actors, the industrial system has also made progress towards forming a European battery industry, as documented by the plans identified in this study to ramp-up production capacity to up to 900 GWh in Europe by 2030 for use in electric vehicles.

In recent years, even raw material producers have seemed to emerge in Europe, planning to produce lithium from mining in south-east Germany and the Czech Republic (Erzgebirge) as well as from the innovative 'mining' of thermal waters in the Upper Rhine Valley.

Finally, the infrastructure side of eVs and batteries is developing through interaction between the transport sector and the energy utilities and even the large oil companies which have started to develop the Trans-European charging system, consisting of different levels of charging stations with up to 350 kW power for long-distance trips and regional networks with lower power but regionally extended coverage. However, the development stage of public charging networks differs between European regions and not all regions are yet prepared, or are even preparing for, the domestic car fleet converting gradually into an all-electric fleet. Nevertheless, the political system is also acting on the issue of charging to ensure minimum coverage of charging stations via the revised alternative fuel infrastructure directive (AFID), as part of the 'Fit for 55' package from July 2021, and the to be revised TEN-T guidelines, as part of the extended 'Fit for 55' regulations.

4. Employment effects

The previous section emphasised that both the European Union and national governments are providing strategic and financial support to attract and keep the automotive industry in Europe. This is especially true in respect of emerging battery cell production, which is seen as one opportunity to preserve the jobs in the automotive industry affected by change. The major transformation taking place in this industry is, however, not limited to the driver of electrification but also reflects the ongoing automation and digitalisation of both production and driving. It is challenging to disentangle and isolate these drivers in terms of their individual impact on employment.

Several studies have been published that analyse and quantify the impact of electrification on employment (Wagner et al. 2019; CLEPA 2021; Schade et al. 2020; Agora Verkehrswende 2021b; BCG 2021; Fraunhofer IAO 2020; Fraunhofer IAO 2019; Ifo Institut 2021). This chapter does not provide a further calculation but analyses the different outcomes – from high job losses to job gains – and thus identifies the differences in assumptions and perspectives that lead to these outcomes. As batteries are the focus of this chapter, we limit our considerations to highlighting the importance of battery manufacturing to overall automotive employment.

In any analysis of the employment effects within the automotive industry, three perspectives may be identified as relevant:

– the sectoral dimension;
– the regional dimension;
– the skills dimension.

Even though some studies conclude that the net employment effects are rather small, tremendous structural changes are taking place across all three dimensions which, ultimately, balance out, giving the overall rather modest effects when viewed generally.

4.1 Consideration of changes within sectors, regions and skills required

The sectoral dimension can range from a narrow view of jobs in powertrain manufacturing to a comprehensive view including adjacent industries such as charging infrastructure. The regional dimension ranges from changes within a country to a broad European perspective. The skills dimension highlights whether the same employees whose jobs are at risk can benefit from the creation of new jobs and how much retraining is required in this process. The choice of the scope considered within each dimension is a decisive factor for the resulting employment outcome and thus also one reason for the differences in forecasts.

The underlying assumptions across all the dimensions include production volume, sales volume, productivity, in-house value added, the production share of PHEV and BEV, and import and export figures. How crucial these assumptions are is shown by the analysis of employment at Volkswagen, which concludes that employment in vehicle manufacturing is expected to fall by 12 per cent by 2029 in the company, although only a small part of this is due to product change per se; the larger part is due to changes in production volumes, production locations and process improvements (Fraunhofer IAO 2020).

The existence of a full European battery value chain is assumed as a given in most studies and identified as a key component for a successful transformation. The great importance of establishing European battery cell production results not only from the labour perspective but rather from enabling upstream value creation and multiplier effects across the existence of the entire battery ecosystem (Fraunhofer ISI 2020). See Section 4 on the innovation system analysis for further details here.

Overall, the personnel requirements for the production of the conventional powertrain are 70 per cent higher than for the electric counterpart (Fraunhofer IAO 2020). The production of the battery cell is, moreover, highly automated which is why the compensating employment effect is limited. At the same time, BCG (2020) has calculated that the labour hours per vehicle for BEV correspond to 99 per cent of those for ICEV for a premium passenger car. Only the distribution of labour hours between tier one suppliers and OEMs vary, depending on the extent of BEV component outsourcing (cell, module, pack, electric motor and transmission, and power electronics).

Finally, even if the employment effect of electrification is limited the question remains open as to the counterfactual against which the impact on employment ought to be measured. If the counterfactual is business-as-usual then it is arguable that employment would shrink as well. Such a strategy would result in significant market share loss and also end up with less employment due to the lack of demand and competitiveness beyond European borders.

4.2 The sectoral and national dimensions of jobs and skills

Employment in the automotive industry can be broken down to employment per individual component. The common result of various studies is that, while a narrow view of individual components shows job losses, a holistic view across all components shows job gains. The electrification trend reveals losses that are offset by the automated and autonomous driving features which, overall, leads to increases in the value created per car (i.e. by its endowment with ADAS components). The most significant assumption for all scenarios is the existence of a full European battery value chain, from raw material processing to assembly.

In the scenario focused only on electric vehicles (in line with the 'Fit for 55' package), the study by CLEPA (2021) results in a net effect of -244 000 FTE jobs in 2035 compared to 2020. This study concludes that the trend of electrification puts powertrain employment at risk. Even assuming a full European battery value chain, the different powertrain technologies are not able to offset each other in terms of employment. The main reasons identified in the study are higher automation, lower levels of manual labour and the very short adjustment time. Despite the latter, sticking too long to ICE and PHEV implies that large proportions of the value chain, and thus jobs, would be located outside the EU.

A further extension to adjacent industries, identifying the sectoral employment effects of a transition to sustainable mobility in Germany, concludes a loss of 128 000 jobs in conventional road vehicle production (ICE) in 2035 while the sector producing electronics, including batteries and cells, would gain 67 000 jobs (Schade et al. 2020).

A similar analysis of the employment effects across various sectors closely related to the automotive industry in Germany, taking into account six identified trends, confirms these results (Agora Verkehrswende 2021b). There are large job losses among car manufacturers (-70 000 jobs), powertrain-dependent suppliers (-95 000 jobs) and in maintenance and repair (-15 000 jobs). At the same time, powertrain-independent suppliers are experiencing strong growth in employment (+95 000 jobs). Related industries, such as plant engineering and services, energy production, energy infrastructure and recycling, are also expected to see positive employment effects (+110 000 jobs). This leads to a net effect of +25 000 jobs between 2020 and 2030. Overall, a loss of jobs in the automotive industry caused by the trend towards electrification is noted, alongside the compensation in full by parallel developments.

The broad sectoral dimension has also been analysed in an overall approach taking a European perspective, including core automotive industries (OEMs, ICE-focused and non-ICE suppliers, maintenance and repair) as well as adjacent industries such as equipment and services, energy production, energy infrastructure and recycling (BCG 2021). The main findings confirm the German study in terms of major losses in OEMs (-220 000) and ICE-focused suppliers (-280 000) but compensated significantly, although not in full, by gains in non-ICE suppliers (+240 000), maintenance and repair (+20 000), equipment and services (+15 000), energy production (+60 000), energy infrastructure (+120 000) and recycling (+10 000). The net effect is a loss of 35 000 jobs.

Regarding the wider trends, the impact of changes in market volume (-70 000 jobs), technology evolution (+65 000), product mix (+250 000), productivity gains (-230 000) and the shift to electric vehicles (-630 000 and +580 000) have all been identified. Analysis of the studies shows a very mixed picture and thus underlines the interdependence of many sectors that are affected by many of the trends developing at the same time, each with different and opposing effects on employment. In general, however, it can be derived that the larger the scope – that is, the more industries and the more trends are taken into account – the smaller will be the expected losses in employment. The loss in ICE component manufacturing cannot be fully compensated by establishing battery cell manufacturing facilities. However, this does come with many positive multiplier effects that increase additional employment in adjacent upstream and downstream industries (e.g. the deployment of charging infrastructure and upgraded electricity grids). Moreover, it is not the only transformation of the automotive industry that we expect by 2030.

4.3 The regional effects

Within the European Union, and even within a country, the differences in employment effects can be significant. For example, the south-west of Germany is strongly affected by job losses in the ICE sector but also benefits from the settlement there of new battery cell production (although eastern Germany is expected to benefit most). Further, at regional level the compensating effects of the transition to electric cars versus ADAS may prevail: some regions in Germany facing substantial losses in ICE-related jobs are compensating for this via their regional IT and electronics industries that will provide ADAS components (Wagner et al. 2019).

Analogously, the employment effects across the EU as a whole look much more differentiated than at national level. The loss in ICE-related supplier jobs is estimated to be highest for Germany (122 000), followed by Italy (66 000) and Spain (64 000). The gain in BEV-related jobs is highest for Germany (39 000 FTE), followed by Spain (37 000 FTE) and France (26 000 FTE). Regarding the net employment effect, France is the only country which slightly increases its total employment by 2040 compared to 2020, although the Czech Republic shows net zero changes. Looking at regions of the EU, one study concludes that the phasing-out of ICEVs is expected to have higher effects on eastern European countries while western European ones will play a key role in developing electric vehicle technologies (CLEPA 2021). This regional consideration is, however, limited to a very narrow sectoral dimension, comparing the employment effects only in the ICEV and BEV segments.

4.4 The skills effects

The trend towards electrification will also shift skills requirements. Overall, 2.4 million positions with dedicated training needs are identified across Europe: about 1.6 million employees remain in their same job profile and require only on the job training; 0.6 million employees require retraining and relocation in a similar job profile; and 225 000 employees require reskilling and relocation with a new job profile (BCG 2021).

The consequence is that sizable employment transitions will occur over time between industries, occupational fields and regions, leading to a diverse picture of job losses, job creation and job upgrading, but emphasising throughout the primary need for continued training.

Table 3 summarises this chapter by providing an overview of the key characteristics of the studies analysed.

Table 3 **Comparison of employment studies**

Study	Period	Value chain	Focus	Country	Trend	Net employment effect
Wagner et al. (2019)	2015-2035	National cell production	Employment per component, full vehicle	GER	Automation, electrification, productivity, market volume, technology, mobility behaviour	+42 000
CLEPA (2021)	2020-2040	Full EU battery value chain including processing of raw material	ICEV and BEV supplier, powertrain component	EU	Electrification	-417 000 in radical scenario; -275 000 in electric vehicle-only scenario; +122 000 in mixed technology scenario
Schade et al. (2020)	2018-2035	National cell production	Transport industry	GER	Automation, electrification, productivity, market volume, technology, mobility behaviour	+234 000 (total economy)
Agora Verkehrswende (2021b)	2020-2030	National cell production	Automotive and adjacent industries	GER	Market volume, technology, product mix, productivity, electrification, job migration	+25 000
BCG (2021)	2019-2030	EU cell production	Automotive and adjacent industries	EU	Market volume, technology, product mix, productivity, electrification	-35 000

Source: M-Five own illustration.

5. Synthesis: What is at stake for the European automotive industry?

The main findings of the previous sections are presented here to outline the possible evolution of European battery cell manufacturing for automotive applications and to identify the strengths, weaknesses, opportunities and threats that can be expected up to 2030.

In 2014, a study on the future of the German automotive industry on behalf of the German parliament identified seven strategic challenges, one of which was the electrification of road vehicles and thus the need to build-up the full battery value chain in Germany (Schade et al. 2014). These seven challenges have converged and most authors now quote the last few years and the decade ahead as the period of the greatest transformation of the automotive industry, with three intertwined mega-trends influencing it: decarbonisation; electrification; and digitalisation. We would also add the emergence of new mobility services as a fourth mega-trend that involves changing ownership and mobility patterns. This chapter focuses on one essential element of electrification: battery cell manufacturing, evaluating its importance for the European automotive industry and for competitiveness and employment.

In the short term, the industry in Europe should and is expected to enter the Li-ion battery cell market. Currently the focus is on optimising NMC technology, whose material composition will be improved by a further reduction of the cobalt content, partly followed by a reduction of the nickel content, making it more cost effective. At the same time, energy density will continue to increase. Market entry into NMC manufacturing is important for Europe to catch up and gain insights into production ramp-up and large-scale battery (cell) production. In the long term, towards the mid to late 2020s, the introduction of solid-state technology, initially with graphite and silicon anodes, and later with lithium metal anodes, is expected. This shift in the technology would provide Europe with the opportunity to establish technological leadership.

A parallel development of battery technology is the route of the further improvement of the specific energy of LFP cathodes to exploit their advantages in terms of more environmentally friendly raw materials, lower costs, higher safety and longer life. Here, China has been a major pioneer so far and its technology might be simply imported to Europe since the development of European manufacturing has been focused on NMC. Improvements in LFP technology could reduce the market size for the NMC technology preferred by the European battery industry. The first European LFP battery cell production plant, in Serbia, has recently been announced and is also backed by EU funds.

Vertical and upstream integration can be expected along the value chain, enabling better control, ensuring high value-added and at least partially offsetting the losses in employment due to the shift to BEV production from more employment-intensive ICEV production. An increasing build-up in recycling capability and capacity can be observed which could be accelerated by legislation in the future. This offers Europe the opportunity to become increasingly independent of volatile and rising raw material prices and security of supply risks, while generating additional value locally and establishing a leading market for green batteries.[7]

Europe appears to be an attractive location for future battery cell production and has already seen several announcements from various manufacturers. If they are implemented as planned by 2030 this would add up to 900 GWh of cell production capacity in Europe. However, there are hurdles to scaling on top of the risk of over-investment and battery 'bubbles', so not all announcements may actually be realised. Nevertheless, rising European demand for batteries and thus cells is accompanied by increasing European production, such that we expect a growing European share of global battery cell production.

With regard to the employment effects, sizable transitions will occur over time while the picture for jobs and skills is diverse. The transformation will have only a minor impact

7. It is also understood in China that green battery manufacturing will become a must, such that efforts will be and indeed are already being undertaken there to certify the sustainability of battery plants.

on the total number of jobs in the automotive industry overall, but major restructuring and a high need for skills must be expected.

Figure 11 provides a SWOT analysis identifying strengths, weaknesses, opportunities and threats for European battery cell production.

Figure 11 **SWOT analysis of European battery cell production**

Strengths	**W**eaknesses	**O**pportunities	**T**hreats
▪ Strong automotive industry ▪ High European demand (sufficient market share for emerging players) ▪ Existing logistics ▪ Strong chemical and materials industry ▪ Attractive investment environment ▪ Access to talented workforce	▪ Lack of access to raw material mining and refining capacity ▪ Need to leapfrog along the learning curve of Asian manufacturers	▪ **Short term**: market entry and catch-up through optimisation of current technology ▪ **Long term**: increasing market share through solid-state and next generation technologies ▪ Building recycling capacity ▪ Localisation and control of supply chain ▪ Vertical and upstream integration of value chain ▪ Building export capacity	▪ Dominance of Asian suppliers ▪ Catching up takes time and entails high costs ▪ Time is short as Asian players are already building capacity globally ▪ Battery \`Bubble\`: not all subsidised projects will succeed ▪ Underestimation of potential of LFP technology

Source: M-Five own illustration and analysis.

The significance of change in European car markets becomes obvious looking at the example of the German market by segment and by powertrain system. Across the ten segments of the market, the top-selling single model usually comes from Volkswagen and is currently the combustion engine version of the VW Golf, which sells more than 10 000 vehicles per month. In September 2021, however, Golf sales were down to 6886, with the Tesla model 3 middle class car ranked second with 6828 units sold, almost toppling the long-established number 1. The signal is clear that an electric car produced outside Germany is close to becoming the top selling single model in the country. This example also shows the importance of the capability of producing batteries in Europe as electric vehicle sales have already grown out of being a niche market and are on the verge of overtaking sales of cars with combustion engines.

The question of what is at stake can also be looked at from the opposite angle, i.e. what would be the counterfactual if Europe did not shift to battery and electric car production but followed the trend of production shares in 2020 with ICE remaining the dominant technology. It is true that our estimate of just 52 000 direct jobs being generated by the large-scale ramping-up of battery cell production in Europe up to 2030 cannot compensate all the job losses arising from reduced ICEV production. This observation also holds when considering the indirect jobs created by logistics, recycling and pack manufacturing. This lost employment constitutes job losses by structural change. However, if industry in the counterfactual continued to focus on ICEV production, sales can be expected to drop as the market continually shifts to electric vehicles due to decarbonisation policies, cost reductions driven by large

Box 3 **Current geopolitical and economic challenges**

Recent crises such as the Covid-19 pandemic, the chip shortage and currently the Russian war on Ukraine highlight the major risks facing the automotive industry such as fragile global supply chains and a high dependence on foreign primary products. This is particularly true for the supply of raw materials. The prices for lithium, cobalt, copper and nickel have risen sharply in 2022 and pose a serious threat to a successful, cost-effective and competitive ramping-up of battery manufacturing and thus of electromobility. While the reason behind lithium, cobalt and copper is high demand in the face of scarce supply, the price increase for nickel is directly related to Russia, which is responsible for about 20 per cent of the global supply of the class 1 nickel required for Li-ion batteries. Uncertainties about future political developments are driving up prices (Economist 2022; Handelsblatt 2022).* However, most companies have long-term nickel contracts and should not be affected immediately by price increases.

Recent developments in battery chemistry, reducing the cobalt content and increasing the nickel content, could be extended by a stronger focus on LFP cells as these do not require cobalt or nickel. The consequences of concentrated raw material extraction and refining in only a few countries and the lack of European control along the entire battery value chain are currently becoming even more visible. These crises are taking place in an environment in which many important investment decisions along the value chain are currently being made and some are likely to be strongly influenced by these developments. As a result, we expect that there will be increased focus on the diversification of raw material sources and less reliance on single or only a few supplying countries, in particular Russia. As priorities shift from cost competitiveness to diversification, prices may rise in the long run.

The sanctions imposed on Russia are leading to a sharp rise in fossil fuel prices which, on the one hand, could drive electrification even further. On the other, technological advances and economies of scale in battery cell production, which have driven the fall in electric vehicle prices so far, could be counteracted by rising raw material prices inverting the trend of falling battery prices and thus leading to a slowdown in the ramping-up of electromobility. This may affect European car production more, for example, than Chinese car production. If China takes over the Russian nickel supply originally intended for Europe, it will be able to supply its products at even lower cost and thus pose a threat to the overall competitiveness of the European industry (Handelsblatt 2022).

It is the responsibility of policymakers and industry to take these challenges as an impulse to develop strategic autonomy, secure access to raw materials and gain control over the battery value chain. In addition, a sourcing strategy that combines diversification and cost competitiveness is required. We expect that high and volatile raw material prices are currently the biggest threat to the electric vehicle industry. However, some increase in prices is likely to stimulate the mining industry to invest in new supply, in particular in Europe. We urge that such investment be made. Finally, taking these developments into account, there is an even stronger case for the accelerated development of battery recycling.

* However, experts expect at least a partial calming of currently exploding nickel prices, as it is short-squeeze activities which have continued to drive price developments on the market. The London Metal Exchange even temporarily suspended trading to avoid market panic (Economist 2022).

electric vehicle markets outside Europe, in particular China, and value change among customers in favour of climate protection. In such a counterfactual, job loss would occur due to the steady losses of market share among European auto manufacturers. Such employment losses would be higher and irreparable compared with the losses due to structural change. These structural changes, while possibly painful in the short run, will allow European automotive and battery industries to remain at the forefront of technological development and to preserve their competitiveness.

6. Conclusions and outlook

In the first decade of automotive electrification, the development and scaling-up of battery cell manufacturing largely took place outside of Europe; that is, in China and the United States. Initial European attempts in the industry (such as Li-Tec Battery GmbH) failed. Nevertheless, this decade was used by European industry and policymakers to stimulate and develop a European innovation system that has facilitated research into next generation cell technologies and to establish new co-operation between OEMs, suppliers, materials producers, research institutions and start-ups. That innovation system spans many European countries from Norway and Sweden to France and Germany to Spain, Slovakia and Hungary.

At the beginning of the second decade of automotive electrification, Europe is now on the right path to develop its own local battery cell manufacturing industry, although Asian and American manufacturers are also investing in factories in Europe. On the one hand, foreign investment strengthens the innovation system in Europe as it increases human and financial capital in Europe. On the other, however, it intensifies competition in the markets for electric vehicles and battery cells between European manufacturers and their global competitors. Employment in Europe of course benefits in general from both the investments of, and local production by, European as well as non-European battery cell manufacturers. While the direct employment effects are limited due to the high level of automation in battery cell production, there are further, indirect and positive employment effects in adjacent industries.

Vertical integration of the battery value chain in Europe is strongly recommended, starting with raw material extraction and refinement and introducing a circular battery economy with investment in recycling R&D and recycling capacities. Some recent projects seem to exemplify this trend, such as lithium mining in Zinnwald or the Upper Rhine Valley, or the recycling demonstration plants of BASF and Volkswagen. Important reasons are that (1) the battery logistics of new and used batteries are complex and costly, so 'local' European production will contribute to overall efficiency and cost advantages; and (2) higher recycling shares in the medium to long term mitigate the risk of raw material shortages and high raw material prices. We expect a substantial risk of short to medium term shortages in raw material supply and recommend early and broad coverage of sufficient supply, especially for lithium, nickel and cobalt. In the long term, new mines will be opened and, together with increasing recycling volumes as well as optimised chemical compositions, will lead to a relaxation in raw material markets.

The main risk in the battery domain seems to be the underestimation of the potential of LFP technology and the associated shift in focus in the market from performance to cost compared to NMC. If technological progress in LFP energy density continues, as we expect, the advantages of low cost and high safety will no longer be compromised by comparably lower energy density. Demand for LFP will thus increase and impede the economic success of some European NMC production plants. However, derived from the announcements made so far, NMC will continue to play the more important role in EU battery cell manufacturing. We do see the potential for European LFP production in lower-cost locations, such as the first announcement of an LFP production plant in Serbia. However, Chinese manufacturers in particular have major advantages in know-how that need to be caught up with in order to establish profitable European LFP production.

Regional imbalances in automotive value creation and employment in Europe are initially increasing with the shift away from the combustion engine towards electrification. However, in the long term we expect the often observed development of transformation in Europe in which production starts from the technologically advanced centres of Europe and shifts over time towards the periphery along with the maturing of the technology.

In the electric vehicle domain, the main risk seems to be the too-strong commitment to manufacturing PHEV in Europe, driven by the more positive stimulus for employment, while the environmental benefits, the policy focus, the technical readiness and the foreign competition are tilted towards BEV, making PHEV life on European and global car markets a short story only. In addition, there is a risk that new players entering the local market will be underestimated and exploit the BEV gap created by the concentration on PHEV to make more competitive offers, especially in the mid and high-end segments. This risk emerges not so much from pure imports (e.g. from China) but it does indicate that the local production of new entrants in Europe, such as Tesla, may challenge the European incumbents.

We do not see any risks in demand for electric vehicles: the main drivers of demand, price and technology developments, and the policy instruments and incentives to stimulate demand, as well as the sufficient supply of electrified models across all segments, are all a given. Currently there is a lead time from the order of an electric vehicle to delivery of up to one year. Additionally, our analysis has focused on the needs and status of batteries for electric car manufacturing. However, we expect strong movements to electrify both buses and trucks by 2030. This will increase the size of the battery market and will lead to additional demand for road vehicle cells and batteries in Europe.

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Chapter 3
Low carbon – low wages? China as a market and manufacturing base for electromobility

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This chapter provides an analysis of the changing structure of the Chinese automotive industry, its production networks and its labour relations in the course of the transformation to new energy vehicles (BEV)[1] as the key technology to achieve carbon-free mobility. The focus of the analysis is the question of how to minimise the employment impact of the transition to zero emissions in Europe, targeted for 2050 under EU policies. To what extent would slower or faster electrification minimise or accelerate potential job losses in the traditional car industry; and to what extent might the switch to BEV produce new manufacturing patterns with higher labour intensity?

China is now the global leader in electromobility, both in terms of production numbers and in the use of electric vehicles, as well as in qualitative factors such as charging infrastructure and mobility services; while it also leads in the production and development of electric batteries, including a strong sector in the mining and processing of raw materials. At the same time, China has also become a key base for multinational carmakers from Europe, the US and east Asia in terms of developing mass BEV production and gaining innovatory knowledge in the world's leading market.

Against this background, the employment effects of electrification must be assessed in the context of the structural changes in production models, production networks and labour practices in these new segments of the automotive industry. Electromobility is driving a transformation, comparable to what took place in the information technology (IT) industry, from the traditional models of 'Fordist' and 'Toyotist' mass production to a modular industry structure with globalised production models. China has become the global hub and testing ground for this restructuring process. In the supply chains of the post-Toyotist electric car sector, new regimes of production are emerging that are based on lower wages, higher labour flexibility, low-level automation and higher labour intensity than in the traditional core areas of the car industry in China and worldwide.

The following sections analyse the key aspects of this transformation, while also referring to the relevant industrial policies and China's particular system of policymaking. Section 1 explains the basic aspects of the transformation of industrial structures and China's role within it. Section 2 traces China's industrial policy in the BEV sector with special emphasis on the battery segment while Section 3 takes a closer look at the latter and examines the strategies of vertical specialisation and integration. Section 4 traces

1. Note that China uses the term new energy vehicle (NEV) for what is known as battery electric vehicles (BEV) in Europe and the US. BEV has been adopted here for reasons of in-volume consistency, with the term encompassing pure electric vehicles.

the regimes of production in the emerging BEV sector and the implications for labour policies. Section 5 presents conclusions and discusses the challenges for global trade unions.

1. The transformation of the Chinese automotive industry in the global context

1.1 Restructuring of the global car industry

The automotive industry has often been portrayed as the lead example of Fordist mass production and consumption, linked with relatively high wages and strong bargaining relationships between employers and trade unions. In the wake of the economic crisis of the mid 1970s, it was at the centre of the restructuring of production models through lean production and modularisation (Womack et al. 1990). This pushed mass production, and thereby capital concentration, in the car industry to ever larger dimensions and limited flexible specialisation as an alternative pathway of capitalist production and growth (Piore and Sabel 1984).

The current changes in the car industry are not merely technological in nature. They mark a comprehensive break in the production models, innovation strategies and company structures that had been established with the Fordist model of mass production since the 1920s and revised under the so-called lean production revolution of the 1980s and 1990s. The changes can be compared to the transformation of other mass production industries in recent decades, in which globalisation and restructuring have led to a fundamental reversal of production models and value chains. IT and electronics manufacturing, textiles, garments and footwear, and furniture making have been at the forefront of such developments (Lüthje et al. 2013a).

With the transition to BEV, the automotive industry is facing similarly deep-ranging shifts in the international division of labour and in the shape of global production networks. This time, it is the major emerging economies, and China in particular, that are playing a leading role in this transformation. Production costs and wages are still relatively low, but China is a leader in the process of innovation and has become an indispensable partner for industrialised countries in the transformation of the industry. Related to the basic trends of technological change, three sets of disruptive factors can be traced which are relatively independent of each other but interrelated. These have been broadly described in the business, labour and academic literature:

– battery electric vehicles: electrification of the car promises a solution to the major environmental problem of car-based mobility – carbon emissions. It therefore offers a lifeline for the survival of the established growth model of the car industry, while rendering much of the know-how and skills of established carmakers obsolete and radically reducing the labour content required to build cars (by up to 40 per cent, according to different estimates (NPM 2021 and BCG 2020)). It also brings in new players from the field of new energy components, especially car batteries and power management systems;

- digital driving and control systems: this can be seen as the most direct manifestation of information technologies becoming a key factor in restructuring. The digitalisation of driving brings in the major players of the IT industry, their models of innovation and market control and their financial power including venture capital. This development is challenging the traditional innovation cycles of the car industry and it implies a potential shift of market control from the brand name manufacturers to the providers of the key components of digital driving systems and their related partners in big data and artificial intelligence;
- digital mobility is the main driver breaking up the model of private car ownership as the dominant norm of consumption (Tyfield 2018). It is shifting the centre of innovation downstream to the networks and applications that enable the shared use of cars, comparable to other industries with platform-based models of innovation such as mobile telecommunications (Thun and Sturgeon 2017). In such environments, hardware and its brand names are becoming a less important element of competition than software, apps and networks. At the same time, car sharing and other mobility networks are de facto becoming public infrastructures (Srnicek 2017) that affect requirements for the development of the hardware product.

1.2 Transformation of production networks: China as a hub and testing ground

These disruptions 'from outside' are related to the internal problems of the traditional accumulation regime of the neo-Fordist automotive industry, accompanied by an expected new push towards automation through the digitalisation of car production (Pardi et al. 2020). The industry has been plagued by structural overcapacity in recent decades, particularly in the wake of the global financial crisis of 2008/09. China and other emerging economies have provided a 'safety valve' to maintain global growth in the face of severe disruptions in developed country markets, helping to postpone the substantial restructuring of the dominant regime of accumulation (Lüthje and Tian 2015). This has been backed by tacit coalitions between global carmakers, mainstream political parties and trade unions to protect the car industry and related jobs.

Today, conditions can be compared to those in the IT and electronics industry on the eve of the personal computer and internet 'revolution' of the late 1980s. Then, the existing global champions – large integrated computer, chips and telecommunications equipment makers, such as IBM, Siemens and Fujitsu – were challenged by newcomers such as Microsoft, Intel and Cisco. These companies not only pioneered sweepingly disruptive technologies but they created a whole new model of innovation and industry organisation that became known as 'Wintelism' (Borrus and Zysman 1997).

This model was based on vertical disintegration and specialisation, the industry-wide modularisation of core components and the separation of product innovation from manufacturing. Brand name control transitioned from the final assemblers to the component suppliers. The assembly-oriented model of innovation and market control in mass production industries such as electronics, automotives, and textiles and garments was fundamentally challenged. Manufacturing was shifted to a new brand of vertically integrated contract manufacturers such as Flextronics and Foxconn that created massive manufacturing sites in Mexico, eastern Europe, south-east Asia and China (Lüthje et al. 2013a).

1.3 The structure and growth model of the Chinese automotive industry

China's automotive industry, now the largest in the world, has seen a double transformation during the past two decades. The 1990s were dominated by the major restructuring of the state-owned automobile firms of the Mao period on the one hand and the emergence of first generation joint ventures between local state-owned holding companies (such as Shanghai Automotive) and foreign carmakers (such as Volkswagen) on the other (Thun 2006). These joint ventures have mainly served the Chinese domestic market, with the key policy goal being to transfer state-of-the-art technology and manufacturing know-how to Chinese carmakers (Lüthje and Tian 2015). Since around 2000, the surge of foreign investment in advanced technologies and manufacturing systems has created a production base comparable with that of industrialised countries, including a growing array of design and development activities (Lüthje and Tian 2015).

Today, production networks in China's automotive industry mirror the globally dominant model of the flexible mass production of standardised car models but in great variety. They are based on the production side on the modular, company-specific platforms promoted by the major producers and, on the consumption side, on private car ownership by the population. At the same time, they are centred on the lean production model with relatively slim core factories for car assembly and global-local pyramids of tier one system suppliers and tier two and tier three parts manufacturers (Zhang 2015).

The top layers of the production networks – that is, the assembly of cars and some strategic components (engines in particular) – are controlled by the joint ventures while the middle and lower tiers of the supply pyramid are mostly owned by private investors (local, foreign or overseas-Chinese), usually with little access to high-level government resources. Multinational tier one car suppliers have expanded rapidly in China, including the presence of sizeable research and development operations. However, the overall picture remains dominated by heavy cost competition and labour-intensive production processes with relatively limited industrial upgrading (Lüthje and Tian 2015).

Against this background, the growth regime of China's automotive industry is split into a capital-intensive high end, dominated by the Chinese state-owned enterprises and their multinational partners, and a fast expanding low end. These smaller carmakers under private or 'hybrid' ownership, such as Geely, Chery or BYD, have emerged and have been able to challenge the large state-owned enterprises in some important markets. These companies have developed extensive production networks at local and regional levels and receive support from interventionist local governments to build supplier networks, infrastructure and technological resources.

This oligopolistic structure was relatively efficient in guiding the major restructuring of the Chinese automotive industry in the late 1990s and its great leap forwards into state-of-the-art production technologies and networks. State-capitalist regulation has also been critical in supporting substantial geographic expansion into greenfield sites in central and western China since the 2008/09 crisis, as well as the globalisation of Chinese state-owned carmakers as investors and shareholders in multinational car companies (such as Beijing Automotive in Daimler and Dongfeng in PSA) (Lüthje and Tian 2015).

Given the challenges in the global car industry, however, serious doubts may be cast over the continued efficiency of this framework. The state-capitalist model not only curbs competition and encourages oligopolistic pricing behaviour, it also limits innovation. Chinese government policies have therefore increasingly shifted to providing further support to newcomer companies in the BEV sector and also in digital driving.

1.4 New players in the Chinese BEV sector

The entry of rapidly growing new players into China's automotive industry is reshaping the traditional model of state-capitalist regulation. It is bringing in innovative firms from the non-state capitalist sector of the industry (independent car and BEV makers, alongside component producers), as well as from the IT industry and from global and Chinese systems suppliers. Significantly, the Chinese government is relying on such new industrial actors, taking account of the success stories of the country's IT and other industries that followed pathways different to the joint venture model.

The IT industry provides the pattern for the current transformation of the automotive industry. The successful development of Chinese brand name firms, such as Huawei, Lenovo and ZTE, into leading national and global firms was achieved in the absence of, or in competition with, firms established under joint venture strategies. In the telecommunications industry, joint ventures of state-owned enterprises with global players such as Ericsson, AT&T and Siemens had been designed in the 1990s to trade technology transfer for market access. The Chinese partner firms reaped substantial profits from making and selling foreign-branded telecoms equipment in rapidly growing urban markets, but they failed to develop brand name products and services for the huge markets in rural areas. This was left to newcomer firms such as Huawei who combined expertise in undeveloped markets with the rapid adaptation of leading-edge technologies from the evolving internet equipment industry in Silicon Valley.

Since the Chinese government began to expand the BEV sector by imposing on carmakers a production quota for electric vehicles (see Section 2), a significant surge in investment in the BEV sector has taken place while incumbent carmakers are suffering sluggish sales and mounting overcapacity. In 2018, the Chinese market for passenger cars contracted for the first time in recent history: in the first half of 2019 sales of passenger cars fell by 14 per cent (Financial Times 2019a). The massive build up of capacity on the part of joint ventures, that had dominated the scene since 2008/09, has come to a halt and, in some cases, such as Beijing-Hyundai, plant closures have become imminent (Daye 2019). On the other hand, independent carmakers and BEV producers have grown rapidly. Geely in particular opened three plants between 2017 and 2019, bringing production capacity to 1.7 million cars per year. In 2017 alone, 14 BEV start-ups in China were granted production licences and most such companies have started building factories. According to the China Association of Automobile Manufacturers, annual capacity for the production of pure (BEV) and plug-in hybrid (PHEV) electric cars hit two million in 2019 (Fitch 2029) and a large number of those BEV start-ups have, by 2022, already started production.

In this context, new regional centres of production and innovation, as well as new power relations between the central and the local state, are emerging. Most of the new players and industry segments are located outside the traditional centres of car manufacturing. Shenzhen and the Greater Pearl River Bay Area (with BYD, Tencent, Foxconn and a huge electronics manufacturing base), Hangzhou (with Geely and Ali Baba) and Fujian province (with CATL) can be seen as core locations. Government-industry relations in these regions are different to the traditional centres of the automotive industry with their strong state-capitalist conventions: the new centres are governed by relatively open forms of regulation with arms-length relationships between activist local governments and privately owned firms.

1.5 The emerging competitive structure of China's green car industry

The emerging landscape developed by the new domestic players in the Chinese car industry can be defined by technology clusters, business models and their relationship to the world market.

Independent car and BEV makers with a background in the automotive industry, such as Geely, Chery, JAC and BYD are building the core of China's domestic green car industry. With its diverse product portfolio of small and medium-sized cars, as well as buses and utility vehicles, BYD has sold more electric vehicles than any competitor worldwide. Geely has established a highly ambitious strategy to convert its Volvo brand completely to BEV, embarking on joint component development and the use of its own low-cost production system (Financial Times 2017). At the end of 2020, Geely entered an alliance with Foxconn for the contract manufacturing of cars, eyeing new entrants into BEV from among top-tier global IT firms (Taipei Times 2021). Foxconn has announced plans to provide 5 per cent of global battery electric vehicles by 2025 (Reuters 2022). Most of the independent car and BEV makers have their own factories and are vertically integrated within Chinese-style conglomerates. They run extensive local production networks, designed to leverage cost advantages for local players.

Digital car and BEV start-ups have also emerged, backed by internet giants, global venture capital and Chinese business tycoons, such as NextEV/NIO, LeEco/Faraday and Baoneng as a second pillar in the sector. Most of these companies are focused on the development of high-end vehicles, similar and in competition to market leader Tesla. Most of these ventures are highly speculative and have received ample publicity although, in the light of some spectacular bankruptcies, their market and financial success still needs to be tested. In contrast to Tesla, these companies are concentrating on design and development and are using contract manufacturers to assemble cars, especially their electronic components. In the wake of Tesla's success in China after the coronavirus crisis, a new wave of speculative investment into Chinese BEV start-ups has occurred.

Integrated new energy and battery producers make up the third segment of this sector in which Chinese companies clearly have the strongest position in the world market (Fraunhofer ISI 2016). BYD is a battery manufacturer by tradition, originally a supplier of lithium-ion (Li-ion) batteries for computers and smartphones to Foxconn and other large electronics manufacturers. In 2017 the company was classified as the biggest producer of Li-ion batteries globally, leveraging vertical integration effects from various end markets such as cars, buses, IT or solar and energy management systems. The second lead firm is CATL, a previously unknown battery maker from Ningde, a rural city in Fujian province. The company has massively expanded production, becoming the world's largest producer in 2020. As part of a major globalisation effort, CATL has announced the construction of a Li-ion battery cells factory in Erfurt, Germany, with an initial capacity of 14 gigawatt hours per year (Dongfang 2019), while in 2022 it started a 7.6 billion euros investment in a 100 GWh battery plant in eastern Hungary (Reuters 2022a). In addition, China's major electronics areas – the Pearl River Delta in particular – have extensive clusters of small and medium-sized battery manufacturers with production experience from the electronics industry (IPRD 2018). This line-up is completed by the large Chinese manufacturing operations of the leading battery manufacturers from Korea and Japan. In 2017, eight out of the thirteen major Li-ion battery manufacturing sites in the world were in China (Sanderson et al. 2017).

Systems suppliers are playing a key role in the transformation of innovation and production networks in the Chinese automotive industry. The situation in this sector mirrors the segmented structure of supplier pyramids under the joint venture model. Tier one multinational suppliers are engaged in the development of digital driving systems and are preferred partners for the big three Chinese internet companies: Bosch has formed a strategic alliance with Ali Baba; Continental with Baidu. However, there is no Chinese supplier of significance that could play the role of system integrator and potential global champion in the BEV and digital supply chain.

Electronics contract manufacturers, most of them based in Taiwan, are already playing a major role in supply chains for car electronics and are moving into BEV and digital car electronics. Foxconn, the electronics manufacturing services giant, has operations in car electronics, including some major facilities in the United States, and acts as a supplier among others to Tesla.[2] The chair of Foxconn has announced the objective of controlling 5 per cent of the global electric vehicle market by 2025 (Reuters 2022b). Given the increasing commodification of BEV and the digitalisation of car components, the large electronics contract manufacturers are appearing as potential mass producers of components for driverless vehicles and BEV. Contract manufacturers are also

2. Guo Taiming, Foxconn CEO, has stated that 'Tesla EVs are virtually made in Taiwan' (Digitimes, 8 January 2018).

securing positions as investors in start-ups of all kinds: Ali Baba and Foxconn have invested 350 million dollars in a BEV start-up named Xiaopeng (Automotive News China 2018); and, in autumn 2020, Foxconn announced a new technology platform for BEV and a network of alliances with Geely and Chinese start-up BEV makers, aiming at the replication in the electric car sector of its contract manufacturing model (Financial Times 2020).

1.6 Changing production models

The traditional carmakers – globally and in China – have recently responded with massive investments in BEV. Companies such as Volkswagen or Ford have begun to produce electric versions of most of their car models and, in the near future, VW has announced that 50 per cent of its sales in China will be BEV (Reuters 2019). VW has created its own global platform, concentrating BEV manufacturing in two dedicated factories in Shanghai and Foshan (Guangdong province). Box 1 sums up the three main scenarios that are emerging as a possible production model for electric car manufacturing. The traditional carmakers are trying to use their manufacturing expertise to retain the old model of vertical integration intact. Yet, their production strategies for NEV are driving new forms of modularity. VW, BMW and other global carmakers are sourcing battery cells externally under large-scale contracts with CATL and other east Asian producers, while limiting their own production activities to the assembly of battery cells in car frames (2019 field interviews). At the same time, the carmakers are aggressively pushing cooperation and cost sharing. In a major alliance, VW will license its newly developed MEB platform for electric vehicles to Ford and potentially to other carmakers (Financial Times 2019b).

The restructuring of production systems and value chains also opens up considerable potential in terms of flexible specialisation. The production of speciality cars, delivery trucks, buses and public transport systems is creating a large array of growth opportunities for BEV. In these markets, as well as in passenger BEV, volumes tend to remain relatively small. Changes in technology as well as government regulations and standards require frequent changes in model line-ups and components.

To cope with such insecurities, major Chinese firms are tending to keep their operations highly integrated but with low degrees of automation. BYD, in particular, is pursuing a strategy to produce batteries and components for new energy systems of all kinds (including smartphones, urban grids and solar systems), among which cars are only one downstream product. Under this model, new energy technologies are being employed in a large variety of products and systems, with economies of scale leveraged mainly on the side of battery production (IPRD 2018).

Three predicted scenarios of restructuring

1. **Refurbishing vertically-integrated mass production through the integration of battery manufacturing by carmakers**
   Brand name carmakers keep control of their hierarchical supplier pyramids; integration of battery manufacturers as specialised suppliers (e.g. Panasonic, LG or CATL) but not controlling production and technology norms.
2. **Vertically disintegrated mass production – battery manufacturers as core component suppliers with an open interface to car assemblers**
   Battery makers control the technology and manufacturing competency norms along the Li-ion battery supply chain – open interfaces with car brands complemented by independent makers of digital drivetrains.
3. **Flexible specialisation of battery manufacturing clusters as core component suppliers of EV**
   Integrated supply chains with co-development of core technological innovations and transfer into quality manufacturing, based on smaller to medium-sized innovative firms using Industry 4.0 technologies for local markets, mobility systems and communities.

2. Industrial policy

2.1 China's national development strategy for new energy vehicles

More than a decade ago, China defined the electric car industry as one of its key strategic development domains in order to meet the future challenges of resources, energy, environment, industrial transition and urbanisation. In 2012, the State Council of China released the Energy Saving and New Energy Vehicle Industry Development Plan (2012-2020), clearly setting out the goal of attaining a production capacity for pure electric vehicles and plug-in hybrid electric vehicles of two million units by 2020.

Since that point, the BEV industry in China has developed rapidly, supported by advantageous industrial policies and subsidies from both central and local governments. In 2018, China accounted for more than half of global EV sales and some Chinese traditional original equipment manufacturers (OEMs) – BAIC, SAIC and Geely – are now among the world's leading EV makers. The best-selling electric car in China is Wuling Hongguang Mini, a four-seater microcar with a starting price of around 5000 dollars (BNEF 2022), while Chinese sales of electric vehicles are forecasted to reach six million in 2022 (BNEF 2022).

This huge domestic market for electric vehicles is backed up by capacity growth in the battery market.

2.2 Changing subsidy policies

The BEV subsidy policy in China has been a catalyst for the rapid growth in electric vehicle production and in the associated component industry. The BEV subsidy policy covers different aspects, the most essential including technical requirements, purchase tax exemption and some practical advantages – priority in registration, city driving and parking. From 2010 to 2019, China issued more than 70 regulations at national level regarding the BEV industry. Importantly, there has been a tightening of the technical requirements enabling the allocation of subsidies. In the beginning, the only subsidy qualification requirement was a minimum energy capacity for the power battery of at least 15 kWh but the requirements are now much broader, encompassing vehicle performance (maximum speed and minimum range) and battery density as well as vehicle energy efficiency (Alochet 2020).

In parallel with the increased specification of technical requirements, the Chinese government announced the full cancellation of direct financial subsidies by the end of 2020, a process which was to be implemented in steps from 2016 with a yearly reduction rate of about 20 per cent. In April 2020, however, due to a slowdown in the BEV market and the severe economic situation caused by the Covid-19 pandemic, the Chinese government decided to postpone full subsidy cancellation to 2022, allowing a longer adjustment period.

The government's plan is to substitute direct financial subsidies with a market-based credit mechanism combining a BEV quota and a credit trading system for carmakers. The New Energy Vehicle Mandate, which came into force on 1 April 2018, imposed BEV credit targets of 10 per cent of new vehicles sold on the conventional passenger vehicle market in 2019 and 12 per cent in 2020 (with continued gradual growth in the following years) for any carmaker with over 30 000 vehicles manufactured locally or imported yearly in China (ICCT 2018). For the time being, this mechanism is in its initial period of deployment, while the trading system is still in construction. The BEV credits mechanism aims to stimulate the intensification of R&D and the technological density of the Chinese automotive industry, rising from battery power to electric range and, finally, to the battery power plus electric range plus energy consumption tripod. The Ministry of Industry and Information Technology (MIIT) has announced that it will continue to intensify such requirements in the future (Muniz et al. 2019).

The gradual phasing out of direct subsidies for buyers has seen the BEV market in China noticeably slow since the second half of 2018. In 2019, and especially in the second half of that year – due not only to the continued reduction of subsidies (at both national and local levels) but also to the complete elimination of subsidies for vehicles with a driving range of less than 250 km – total BEV sales were only about 1.2 million units, a decrease of 4 per cent compared with the same period in 2018. With the impact of Covid-19 on consumption, the BEV sector further suffered very weak demand in the first half of 2020. Even without the consequences of the pandemic, BEV producers are still facing major challenges with the full cancellation of the direct subsidy in view. One solution being explored is to reduce the sales price of vehicles in order to win bigger market share and, at the same time, guarantee minimum production volume to reach economies of scale.

As the battery represents over 50 per cent of the overall cost of an electric vehicle, battery firms are among those in the BEV value chain experiencing the biggest impact of this slowdown. OEMs generally requested that battery firms reduce prices by 20-40 per cent during 2019; that year, the average battery pack price reached 147 dollars/kWh in China, which was the world's lowest. Price pressure has thus become a major structural market feature.

2.3 Environmental policies in the BEV battery sector

The tightened policies on subsidies have themselves had an upgrading effect on quality and environmental standards. However, health and safety supervision and environmental regulations on Li-ion batteries are relatively loose in the Chinese market, the major issue being that policy implementation in this field experiences substantial deviations. According to the China Automotive Technology & Research Centre, the total number of retired power batteries in China was about 200 000 tons in 2020, of which a large number have flowed into informal shadow market channels such as small workshops, causing potential pollution risks to water, land resources and human safety (Xinhua News 2021).

In July 2021, China's major economic policy decision making body, the National Development and Reform Commission, published the Circular Economy Development Plan during the 14th Five-Year Plan Period, highlighting for the first time in a general national development plan the importance of BEV battery recalls. Four tasks were identified:

1. promote the establishment of standardised recycling service facilities through BEV manufacturing enterprises, battery recycling enterprises or their collaboration;
2. promote the standardised cascade utilisation[3] of power batteries and improve technical capacity in the area of residual energy detection and residual value evaluation;
3. strengthen the application of advanced integrated equipment in respect of the recycling and cascade utilisation of power batteries;
4. improve the standardisation of power battery recycling.

As the main administrative body for the environmental and safety regulation of BEV batteries, MIIT has issued several directives on industrial standards regarding Li-ion batteries based on technical advice from the major enterprises in the industry, while it has also led the organisation of a technical committee to coordinate the management of the cascade utilisation of BEV batteries. In addition, policy coordination is also emphasised by the regulatory authorities. In principle, the State Administration for

3. Cascade utilisation seeks further uses for decommissioned Li-ion batteries originally used in electric cars for other products in other sectors, thus extending the life of the battery and maximising its use value.

Market Regulation mainly supervises the quality of battery products; the Ministry of Ecology and the Environment is in charge of environmental pollution prevention and control in the production process of the cascade utilisation of batteries; and the Ministry of Commerce conducts the supervision of enterprises that dismantle scrapped BEV vehicles.

In reality, however, the fragmented nature of the Chinese administrative system places considerable difficulties on policy coordination.

2.4 BEV battery recycling

In 2018, MIIT, together with four other relevant ministries, issued interim regulations on the management of the recycling and traceability of electric vehicle power batteries. These proposed to implement an extended producer responsibility system and the full life cycle management of BEV batteries, stipulating that vehicle manufacturing enterprises should be the main responsible parties for battery recycling. According to the regulations, information collection is required for the entire process of power battery production, sales, use, scrapping, recycling and re-use. An integrated traceability management system, based at the Beijing Institute of Technology, as well as a national platform, were proposed for enterprises to upload product information in the form of manufacturer codes.

In 2021, MIIT issued administrative measures for the cascade utilisation of electric vehicle power batteries under which, in order to utilise used batteries further, enterprises are encouraged to develop technologies applicable to facilities such as base stations and energy storage production. They are prevented from applying used batteries to products that cannot be further recycled and in areas that pose high environmental or safety risks. A number of pilot projects have been established to encourage cascade utilisation.

Meanwhile, in March 2021, an online platform for retired battery trading was launched in the Nanhai District of Foshan City in Guangdong. Traders are able to find a list of BEV power battery recycling service stations across China and can also publish purchasing and selling information about retired batteries and seek power battery performance evaluation and laboratory testing services.[4]

3. BEV battery production as an emerging core sector

3.1 Rapid growth but looming overcapacity

Largely due to the development of the domestic BEV industry, the Li-ion battery sector in China has also experienced fast growth since 2014. Benefiting from favourable policy and the generous subsidies of the Chinese government, many firms have entered

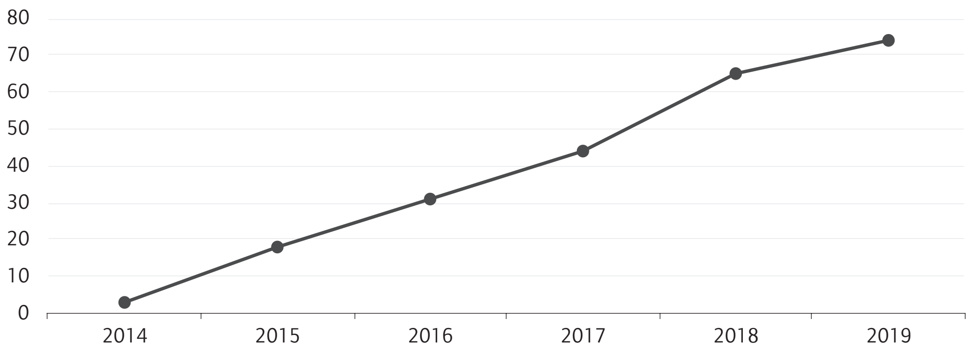
4. https://dianchizhijia.com/home/retireBattery

different positions along the value chain of the sector in a very short period. BYD planned to reach 90 GWh production capacity by the end of 2020; CATL, representing 50 per cent of the domestic market in 2019, projected a production capacity of 54 GWh by the end of 2020; and other leading battery firms (Gotion Hi-Tech, Tianjin Lishen, Farasis Energy, National Energy, BAK) are also increasing their capacity to 20-40 GWh within the same period.[5] Besides using specialised battery firms, most OEMs are vertically moving to the self-supply of batteries or are otherwise building joint ventures with battery firms.

According to the adjusted growth targets proposed by MIIT in December 2019, by 2025 BEVs will contribute about 25 per cent of annual vehicle sales in China instead of the 20 per cent seen initially in the 2012-2020 Development Plan. The main reasons for the adjustment are increased production capacity, the improved technological level and growing global demand, as well as the need to provide a guide to further investment and technology upgrading. Under the government's plan for 8.75 million BEV sales by 2025, the power demand for Li-ion batteries will reach more than 500 GWh within China itself.

Even though BEV sales slowed in 2019, the Li-ion battery sector still registered significant annual growth: total sales reached 75 GWh, with an increase of 15.3 per cent compared to 2018; while installed capacity reached 62 GWh, an annual increase of 9.2 per cent. In 2019, 73 per cent of total global Li-ion battery capacity was located in China, with the US taking second place with a 12 per cent share (Rapier 2019).

Figure 1 **Market growth of BEV-used Li-ion batteries in China**



Source: Gao Gong Industry Institute (GGII), 10 March 2020.

The rapid expansion of capacity by Chinese Li-ion battery producers has, however, resulted in a relatively low utilisation rate as BEV sales still represent only about 5 per cent of total annual vehicle sales, thus causing a problem of overcapacity. According to figures published by Gao Gong Industry Institute, the total production of Li-ion power in China reached 44.5 GWh in 2017, 8.1 GWh higher than actual demand; the overall

5. Author's calculation from company reports and announcements.

inventory accounted for about 18.2 per cent of total output; while the national power battery capacity utilisation rate was only 40 per cent. Behind the exciting developments in the electric vehicle market, such data indicates that, in contrast, the power battery sector was, at least at that point, suffering from severe overcapacity.

3.2 Sectoral policy: from infant industry protection to market competition

Back in 2016, in order to inhibit foreign competitors and protect China's nascent Li-ion industry, MIIT introduced a catalogue of standards for the automotive power battery sector, commonly known as the 'pass list'. According to this document, only those battery models which were fully-owned by local battery manufacturers were included on the list and, in consequence, qualified to receive BEV subsidies from the government. Since all the recommended BEV battery cell suppliers were domestic, this measure acted to push Japanese and South Korean battery firms, such as Panasonic, LG Chem and Samsung, out of the Chinese market, providing a window for Chinese firms to build their own comparative advantages through methods including technology absorption, economies of scale, supply chain lock-up effects, etc.

On 22 May 2018, the new 'pass list' included for the first time three Chinese joint ventures with foreign battery leaders, namely Samsung (50 per cent), LG Chem (50 per cent) and SKI (40 per cent), releasing a strong signal of reduced protectionism and stronger market competition. At the same time, China implemented the full opening up of its automotive market to foreign investors: no form of joint venture was to be required any longer when foreign companies invested in the Chinese automotive industry. Tesla was the first to invest and own its Gigafactory in Shanghai.

Since then, foreign battery firms, in particular the leading firms from Japan and South Korea, have made a strong comeback in the Chinese market, investing in new battery plants aiming to supply OEMs both of their own nationality and also of Chinese:

- Panasonic plans to build up to 75 GWh/year battery capacity in three locations;
- LG Chem is planning a 23 GWh/year battery facility in Nanjing (Jiangsu) by 2023;
- Samsung SDI wants to reach a total of over 35 GWh/year battery capacity in three locations by 2022;
- SKI has opted for battery joint ventures, one with BAIC in Changzhou of 7.5 GWh/year capacity; and another with EVE Energy in Yancheng of up to 28.5 GWh/year capacity.

Currently, foreign battery firms are mainly supplying foreign-owned OEMs or joint ventures: LG Chem sells its batteries to Tesla and the former joint venture of Dongfeng-Renault (now fully owned by Dongfeng); SKI supplies the joint venture of BAIC-Benz; Panasonic and Sanyo supply the joint venture of GAC-Toyota; and Samsung SDI is the supplier of SF Motors. With progressive market opening, foreign suppliers will compete with Chinese battery firms both in the domestic and overseas markets.

As the policy of protectionism has changed and entry barriers have been lifted, one major challenge for Chinese battery firms is the strong level of competition from foreign battery firms which still have some comparative advantages in terms of core technologies and quality management. Besides the traditional strategies, including stronger R&D efforts as a means of improving battery technology – larger production scale to reduce unit price; a better battery system solution to reinforce overall performance – Chinese battery firms are also considering other strategies for downstream integration and cooperation, such as forming alliances and joint ventures with OEMs or tier one suppliers. We describe more examples in the following section. These different strategies will accelerate the consolidation of the battery sector and lead to the deeper evolution of the industry.

Market opening goes along with the reduction of subsidies, showing a typical Chinese pattern of industrial policy adaptation. In the Li-ion battery sector, industry policy has evolved throughout different development stages. After the initial phase of protecting the nascent industry, a sufficient number of domestic players had been established. With the potential risk of overcapacity, policy support changed to stimulating core technology innovation and consolidation among battery manufacturers. Chinese policy makers hope that market selection will promote firms that offer the best performance, have better innovation capacity and show higher competitiveness.

3.3 Value chain strategies of Li-ion battery firms in China

As macro-industrial policy initially enabled the rise of China's electric vehicle battery sector, firm-level strategies and choices progressively responded to this impetus. Indeed, battery firms in China quickly deepened their capabilities in R&D and the mass production of battery technologies and products. Driven by demand, a large quantity of products became available in the market and production capacity continued its rapid increase. Strong linkages and interactions between users (BEV car), producers (BEV battery) and suppliers (BEV components) have been created through the active development of mainstream firms, further strengthening the localisation of the electric vehicle battery value chain in China.

As a result, market consolidation has taken place, with the number of battery firms significantly decreasing, from about 240 in 2015 to only 69 by the end of 2019. This process will be continued in the coming years. At the same time, a trend of internationalisation through different strategies (greenfield investment, mergers and acquisitions activity, strategic cooperation, etc.) is also observed among leading Chinese battery firms which demonstrates China's deepening insertion in the global value chain. CATL is building its first overseas battery plant in Germany, with a planned capacity of 14 GWh by 2022, in order to supply European OEMs such as BMW, Volkswagen, Daimler, Jaguar Land Rover and PSA. CATL has also formed a long-term strategic cooperation agreement with Bosch to produce 48-volt batteries. Gotion Hi-Tech's wholly owned subsidiary and Tata AutoComp from India have signed an agreement for the joint design, development and production of Li-ion cells, packs and a battery management system. BYD is considering building a battery cell factory in the UK to supply Jaguar Land Rover. Envision AESC, the battery sector fund of Envision

Group (a Chinese pioneer in the energy internet of things), has acquired 80 per cent of Nissan's power battery business.

The dominant practice of core firms In the Chinese Li-ion battery sector can be analysed as a value chain strategy. Table 1 summarises the strategic moves of all relevant players in terms of their activities with the rows representing value chain segments and the columns the different types of relevant firms, while the cells describe firms' strategic positioning and entries. The value chain strategy in the Chinese Li-ion battery sector is characterised by two combined aspects:

- growing through vertical integration. Upstream firms integrate forwards to downstream segments, including battery recycling and energy storage; downstream firms integrate downwards to upstream segments such as materials or components. Midstream firms undertake both forwards and backwards vertical integration. Vertical integration is realised by acquiring or creating new assets by means of mergers and acquisitions, strategic alliances, industrial co-operation and greenfield investment;
- competition based on industrial specialisation. When Li-ion battery firms grow through vertical integration in the value chain, they do not abandon their original segments and business (the shaded areas in Table 1). On the contrary, firms continue to compete in their original market and try to become more specialised in their original segments as bases for further market expansion and growth.

A common characteristic of the behaviour of different firms is that the strategic moves are taking place mostly within the boundaries of the Li-ion battery value chain. The field of specialisation is around battery-related technologies. Vertical integration and entry are mainly directed at the various segments of the battery sector, from upstream to downstream. Even for the more diversified downstream activities, they are all based on specialised production, service and technology with regard to BEV power batteries. The framework of the value chain has become the major reference point for the strategy choices of firms at different stages of the Li-ion battery chain in China.

As we explained above, the boundary between Li-ion battery manufacturers and OEM carmakers is still relatively open. Our findings show that not only OEMs but all players in the Li-ion battery value chain in China are adopting vertical integration strategies at various levels of production networks. This adoption of a vertical integration strategy by all the major firms in the battery value chain has resulted in the emergence of a bundle of specialised players who have quickly occupied every stage of the battery value chain, capable of supplying OEMs with lower costs and flexibility. Thus, the Chinese development pathway is highly complementary to the vertical integration strategies of OEMs. It supports a BEV industry based on the vertically specialised mass production of various interacting industry segments, similar to the electronics and other high-tech industries.

Table 1 **Firms' strategies for BEV battery value chains in China**

Value chain segments / Firm category	Raw material mining and refining	Li-ion battery materials production	Li-ion battery cell, module, pack and battery management system manufacture	Electric powertrain system production	BEV assembly and production in China	Battery charging station	Reuse and recycling of Li-ion batteries	Diversified energy saving and storage segments
(1) Mining and refining firms	Minmetals, Jinchuan, Huayou	Minmetals, Jinchuan, Huayou	Minmetals				Jinchuan, Huayou	
(2) Li-ion battery materials producers		Corun, Shanshan, HTECH, Tinci	Corun, Shanshan, Tinci				Corun, Shanshan, GHTECH, Tinci	
(3) Incumbent Li-ion battery manufacturers	CATL, BYD, Sunwoda	CATL, BYD, Sunwoda	CATL, BYD, Gotion, Lishen, EVE, Farasis, BAK, Sunwoda	BYD, Sunwoda	BYD, Sunwoda	BYD, Sunwoda	CATL, BYD, Gotion, Lishen, BAK, Sunwoda	CATL, BYD, Gotion, Lishen, EVE, Farasis, BAK, Sunwoda
(4) OEM producers of BEVs			(a) BYD, Geely, FAW, National New Energy, VW, Weltmeister, Great Wall (b) BAIC, Dongfeng, Changan, SAIC, GAC, Geely, FAW, Daimler (c) VW (Gotion), Daimler (Farasis), Geely (LG Chem), Wanxiang (A123)		BMW, Tesla, VW		BYD, Geely, BAIC, SAIC, BJEV, Dongfeng, Changan, VW, Daimler	
(5) Specialised recycling and dismantling firms	GEM	GEM					GEM, Brunp, Haopeng, Miracle	GEM
(6) Start-ups and new players in BEV & battery sector			GREE, Zhongli, Evergrande, Envision Baoneng		Baoneng		Baoneng, Weltmeister, China Tower	Baoneng, Weltmeister, China Tower, ZTE

Source: Author's data collection from industrial news and company announcements.

4. Production regimes and labour policies

These changes within value chains have a potentially huge impact on work and employment in the automotive industry which has barely begun to be researched. Early estimates and the beginnings of job reduction programmes at global carmakers indicate that substantially fewer workers will be needed for BEV manufacturing and that the traditional mechanical skills of car workers and engineers will be devalued (HBS 2012). Even so, the impact of changing value chains and relocation is not included in most studies. As the electronics industry demonstrated, the revolutions in technologies and business models in the 1990s initiated a massive transformation of manufacturing. In its course, most traditional computer and telecommunications production was closed down or sold off to contract manufacturers and relocated to emerging economies (Lüthje et al. 2013a).

4.1 'Foxconnisation' of car manufacturing?

In the Chinese car industry, massive state-of-the art production bases have been developed during the recent two decades. However, job losses among core global carmakers and in their home regions have been less severe than in comparable industries, e.g. electronics. Due to the expanding Chinese market, most carmakers have duplicated their production networks rather than use China as a location for low-cost export-oriented production. However, this may change in the course of the current transformation towards BEV.

As we have explained already, this implies a break in the existing competitive structure and production models in the Chinese car industry – between incumbent joint ventures with relatively upscale wages and working conditions on the one side; and their competitors from independent carmakers and the IT industry on the other which mainly rely on low-wage manufacturing workforces with high proportions of rural migrant workers.

The sectoral transformation of China's car industry traced in the preceding sections also involves complex restructuring and recombination of the existing regimes of production (Lüthje et al. 2013b). In the joint ventures of the leading OEMs, the globalised model of state-capitalist regulation is aligned with regimes of production that combine the practices of transnational carmakers with the party-based management systems of their Chinese partners. This has resulted in the characteristic twin structure as regards the shopfloor of western and east Asian corporate lean management styles and state-bureaucratic practices (Lüthje and Tian 2015). Today, the core factories of the joint ventures are experiencing increased cost competition and slower market growth. Workforce reductions and plant closures have been seen in the major car manufacturing centres of China.

Most carmakers have started to incorporate the manufacture of electric or hybrid vehicles into their existing production lines, adding new flexibility requirements for factory organisation and workers. Increased pressures have led to workers' dissatisfaction over the deterioration of pay, benefits and employment prospects, especially for temporary workers. In one case, FAW-VW in Changchun, this resulted in a major labour conflict with temporary workers in 2017 over the principles of equal pay for equal work.

Concerning independent carmakers, BEV and battery producers, most such companies rely on vertically integrated production with high flexibility and workforces whose wages are substantially lower than in the joint ventures. The rule of thumb among industry experts is that nine dollars is the standard hourly wage at the top joint ventures, compared with 4-4.50 dollars at independent carmakers such as Geely and BYD (Automotive News China 2017). The lower wage scale is especially prevalent in companies with a background in the electronics industry such as BYD and most of the battery manufacturers.

Their regimes of production represent a high-performance type of labour relations which has been adapted from Korean, Taiwanese and US models. Wages and employment conditions are fairly decent, but the system is highly incentive-based. Skilled employees can achieve considerable extra income and promotions, but work organisation is based on relatively low base wages and salaries, usually less than 50 per cent of regular monthly incomes. Production workers, many of them migrants, are forced to work overtime to achieve a living income (Lüthje et al. 2013b). The production systems of these companies are very flexible but rely on a core of relatively experienced skilled or semi-skilled workers. One of the leading firms of this kind is maintaining its operations in two large industrial parks in south China, one employing 20 000-30 000 workers and the other over 70 000 (2017/18 field research and interview data; IPRD 2018).

Electronics contract manufacturers in China are notorious for their poor working conditions and low wages. Their very large factories, many of them with 100 000 workers or more, represent a regime of flexible mass production that draws its unique characteristics from China's system of internal labour migration (Lüthje et al. 2013b). This is based on the large-scale employment of rural migrant workers in the coastal provinces or major city inland locations, with base wages at the local legal minimum and massive amounts of overtime, often beyond the legal limits. Work is extremely segmented and deskilled, designed to facilitate mass recruitment and lay-offs according to market conditions. Workers are mostly housed in dormitories, often with harsh living conditions. With the increasing role in BEV and digital car production being played by electronics manufacturing services contract manufacturers, such working conditions are expected to penetrate the supply chains. Trade unionists in developed countries, therefore, speak of the 'Foxconnisation' of car manufacturing.

Systems suppliers have diverse regimes of production, reflecting the segmented structure of the industry and their positions in the supply chain: tier one multinational suppliers have high-performance production regimes; while those in joint ventures with state-owned Chinese carmakers have state-bureaucratic forms (Lüthje et al. 2013b). In China, the industry generally operates with wages which are much lower than in the core joint ventures, including tier one multinationals such as Bosch or

Denso. The lower levels of the industry in China are typically traditional low-wage outfits, comparable to the flexible mass production regimes in the IT industry or the ‘classical’ low-wage environment of labour-intensive small and medium enterprises.

A recent study of the supply sector in south China indicated that the shift to BEV car manufacturing and automation has not yet caused major restructuring among suppliers in the middle and lower tiers since most car manufacturers in this region remain focused on traditional car technologies (Yang et al. 2019). Automation, however, does have a potentially heavy impact on the low ends of the supply chain. Recent studies of metal-related manufacturing industries in Guangdong province found that relatively simple forms of automation (mostly with Chinese-branded low-cost robots) led to the massive replacement of manual labour, often affecting the most experienced workers in physically challenging labour processes such as the machining of metal or the polishing of stainless parts (Huang and Sharif 2017).

4.2 Automation and digitalisation of production

The transition to BEV manufacturing and its impact on employment and production regimes must be seen in the context of the technological and organisational changes in automotive manufacturing which have arisen through automation and digitalisation, often described as the ‘fourth industrial revolution’, or ‘Industry 4.0’. In China, this agenda has been mainly promoted under ‘Made in China 2025’, the national core programme promoting advanced manufacturing methods in leading industries.

The car industry as a whole is not listed as a strategic sector under ‘Made in China 2025’; only BEV is included among the ten emerging industries within this programme. Some carmakers, in particular from Germany, are taking part in highly publicised promotions of German-Chinese collaboration in the context of Industry 4.0. But in reality, Industry 4.0-type manufacturing schemes are not significant on the shopfloor. The prevailing tendency of rationalisation is to solidify and optimise the methods of lean production and to improve efficiency under the conditions of China’s ‘new normal’ with much lower growth rates than in the previous two decades (Lüthje and Tian 2015).

This situation reflects a general tendency in the global car industry: since the level of automation in the core sectors of automotive manufacture is generally high, there is no significant incentive to implement radically new schemes of digital manufacturing. In China, state-of-the-art technologies have particularly been promoted through the massive construction of new car plants in the wake of the global financial and economic crisis of 2008-09. Most of these factories have been set up in greenfield locations in central, western and southern China outside the established centres of the car industry. These factories have been built on the bases of the most current platform, production and supply chain strategies of the global carmakers, some of them as global model factories for the respective company (Lüthje and Tian 2015).

This investment rush has been heavily subsidised by central and local governments, as well as by the extensive construction of road and highways infrastructure. It has resulted in a massive expansion of production capacity which has often remained underutilised in the face of slower growth rates and the shifting of demand to cheaper Chinese cars and BEV. The main goal of rationalisation in these factories is to increase the efficiency of the existing production processes in order to improve profitability in times of declining rates of profit. However, a major restructuring of production schemes and value chains is currently happening in the BEV sector and among car suppliers at the middle and lower ends of the supply chains (at least, outside of south China).

In BEV, manufacturing volumes are still rather low and subject to frequent changes of models, technical standards and government requirements. Against this background, manual assembly forms prevail among the indigenous Chinese carmakers. Major global car firms have, up to now, mostly integrated electric models into their existing assembly operations, based on the platforms for their traditional cars. The recent upsurge in BEV production (stemming from the BEV production quota imposed by the Chinese government in 2018) has not changed this situation significantly. The major multinational carmakers have recently dedicated entire factories to volume BEV production, such as FAW-VW with its ultra-modern plant in Foshan, Guangdong province, using VW's new dedicated platform for electric vehicles.[6] However, the slow growth of sales of the electric vehicles of VW and the other incumbent carmakers, and the preference thus far of Chinese consumers for Chinese-branded electric vehicles, have prevented foreign carmakers from playing out their leadership in mass production and setting the benchmark for new production models in China.

4.3 Uneven development along production chains

A major drive towards automation and digitalisation is underway in battery production. The challenge here is to gain control of the mass manufacture of large-scale Li-ion batteries for electric vehicles. Up to now, the volume production of this type of battery has been confined to small batteries for IT products such as smartphones or laptops, where Chinese manufacturers command ample experience. South China, the leading centre of IT manufacturing, hosts the largest supply base for Li-ion batteries in the world. The transition to volume production of large-size batteries requires substantial automation and highly capital-intensive equipment. There is massive potential for digital automation, promoted under 'Made in China 2025', especially in the mechanical parts of the production process and in materials handling. Battery factories, therefore, are seen as model applications for advanced manufacturing under the related national and local programmes (IPRD 2018).

In the supply industry, automation and digitalisation is driven by two factors. Major Chinese tier two or tier three suppliers, such as CITIC Dicastal in wheel alloys or

6. 2017-18 field interviews; 'VW Group doubles capacity of South China plant' *Automotive News China*, 26 June 2018.

Desai in car electronics, have developed extensive automation projects in production and supply chain management. Some of them are hosting model projects for factory automation under 'Made in China 2025'. These companies represent the type of mid-market mass manufacturer outlined above, transforming large-scale assembly operations from mainly manual processes to semi-automated ones. However, the nature of this rationalisation is rather conservative, with a strong focus on cost cutting, quality improvement and the expansion of manufacturing databases. In car electronics, this development intersects with the transformation to BEV production since some of the major Chinese producers are also engaged in the manufacture of battery control systems or battery packs and cells.[7]

At the lower ends of automotive supply chains, basic processes of metal parts manufacture, such as grinding, milling and polishing, are typical application fields for low-end robots. Companies are mostly using relatively cheap equipment from Chinese producers, although some are also importing robots from top international brands such as ABB, Kuka or Yaskawa, configured by local Chinese firms. The purchase of Chinese-made or configured robots is heavily subsidised by local governments (usually between 30 and 60 per cent of investment costs); consequently, investment strategies are short-term, usually with a return on investment target of less than three years. Such robots are typically used to displace semi-skilled migrant workers with long work experience and relatively high wages, who are difficult to find in local labour markets. Automation of this kind replaces the best-paid groups of migrant workers (from rural China), but usually there is no retraining to qualify them as operators or programmers for automated equipment (Butollo and Lüthje 2017).

A recent study of the automation and labour policies of automotive industry suppliers in south China confirms the dynamics of catch-up automation under the conditions of China's 'new normal' (Yang et al. 2019). The study included ten tier one and tier two suppliers to Chinese-Japanese joint ventures in the Pearl River Delta. All of them had been involved in a major wave of labour conflicts in 2010 and subsequently participated in the introduction of democratic union elections and collective bargaining at plant level, seen as a model for China. Production processes in those companies have been continuously automated in recent years and have become more capital intensive. Automation, however, has mostly been gradual in nature, designed to improve quality and efficiency and to reduce labour costs. Digital technologies and robots do not play a prominent role in the rationalisation strategies of those companies while 'Made in China 2025' and related local policies cannot be seen as a major driver for shopfloor change.

Automation is clearly having an impact on workplaces and workers, but in no way as dramatic as the political slogan 'robot replaces workers' might suggest.

7. 2017/18 company interviews.

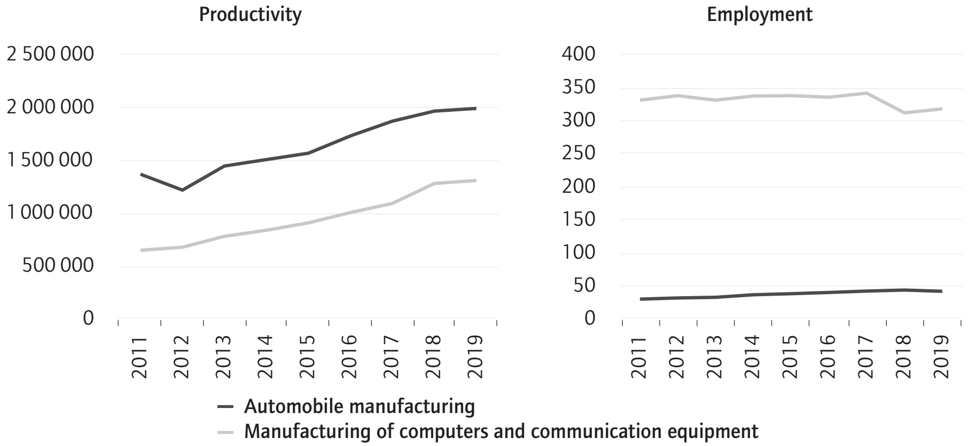
On the whole, the employment effects of both the transition to BEV and of automation and digitalisation in the Chinese car industry are difficult to measure in quantitative terms. Obviously, the shift of BEV production networks into the electronics sector, as well as the relatively low level of automation in the assembly of electric cars and their components (with the exception of batteries), can be seen as a trend towards higher labour intensity in automotive manufacturing. This may offset some of the job losses in the industry resulting from the less complex manufacturing processes in BEV production. On the other hand, automation and digitalisation will continue to progress rapidly in electronics manufacturing and in BEV production networks. Therefore, job reductions through automation are to be expected as a long-term trend in BEV manufacturing, especially in its more labour-intensive segments.

These tendencies can be assessed through a comparison of productivity and employment data in automotive and electronics manufacturing in China. Recent data from Guangdong province, China's largest manufacturing region and a core location for the global electronics industry, as well as for the production of BEV and traditional cars, shows divergent trends for both sectors (see Figure 2):

- automotive manufacturing has very high productivity measured in terms of output per worker (in RNB, 100 RNB=13.5 EUR). But productivity growth has been only moderate, around 45.5 per cent, between 2011 and 2019, while employment grew only slightly during that period. These figures reflect the position of the main car factories in the region, namely of the joint ventures of Toyota and Honda (with Guangzhou Automotive) and Volkswagen (with FAW), being established between 2007 and 2012 as greenfield facilities with very high degrees of automation;
- manufacturing of computers and communications equipment (IT) has the second highest productivity, but this is significantly lower than in automotive manufacturing. However, overall labour productivity has grown much faster, increasing by more than 101.7 per cent between 2011 and 2019, whereas employment has remained largely stable. Traditionally, IT manufacturing included a high proportion of manual assembly, but the sector has seen massive automation during the last decade (particularly in labour-intensive assembly shops at the lower end of supply chains).

With more than three million employees, the IT industry remains the largest industrial sector in Guangdong, whereas employment in the automotive industry is much lower (below 500 000, including supplier firms). Therefore, the potential for automation-related job losses is much higher in the manufacture of computers and communications equipment than in the highly automated car industry. BEV production will certainly add new products and production lines to the electronics industry, although whether this compensates for job reductions through automation remains to be seen.

Figure 2 **Productivity (RNB/worker/year) and employment (thousand persons) in automotive and electronics manufacturing in Guangdong province, 2011-2019**



Source: Guangdong Statistical Yearbook.

4.4 Work processes in Li-ion battery manufacturing: observations from factory visits

The work process in the manufacture of Li-ion batteries has not yet been studied systematically. It is very different, however, from the manufacture of traditional lead acid batteries, which were notorious in respect of severe toxic health hazards for workers, especially in developing countries including China. Most of the core processes of the manufacture of Li-ion batteries are highly automated and this includes printed circuit boards and mechanical assembly familiar from the electronics industry. In the absence of systematic studies, we provide here a first description of the manufacturing process along the industrial chain from factories in the Greater Pearl River Bay Area that we visited between 2017 and 2019.

In general, Li-ion battery manufacturing is highly automated and does not usually require large factory workforces as in traditional car or electronics production. According to figures published by the companies themselves, China's largest battery maker, CATL, has a total workforce of roughly 20 000 people, distributed across nine factories (including the newly established one in Erfurt) and R&D facilities, most of whom are located at its headquarters in Ningde, Fujian province. The workforces of other battery manufacturers appear to be much smaller.

Some of the leading battery manufacturers are concentrating their production on large industrial campuses that include upstream and downstream production processes, such as cell or electronics assembly and the manufacture of electric vehicles or electronics products. BYD focuses most of its production on three large campuses in Shenzhen and Huizhou, each of which has several tens of thousands of employees. Battery factories are located within these industrial parks, which also include R&D facilities, logistics and large dormitories and apartment buildings for workers. Similarly, the joint venture battery factory of CATL and Guangzhou Automotive Corporation (GAC) is located in GAC's large industrial park for new energy cars in the Panyu district of Guangzhou City. Furthermore, what is presumably the largest battery factory in the Greater Bay Area is located in Huizhou and has also been developed as an integrated industrial park in a rural greenfield location. The workforce consists overwhelmingly of migrant workers housed in dormitories.

Along the production and industry segments identified above, the following profile of the work process can be drawn (this does not include refining, the production of basic materials and recycling, since we did not have the opportunity to visit the relevant facilities).

Production of anodes and cathodes is an industrial manufacturing process that includes metallisation, metal forming and die-casting. It is performed in small-to-medium sized factories and includes heavy physical work with a high impact from noise, fumes and high temperatures.

Production of battery cells, the core process, is highly automated and occurs in large cleanroom-like facilities. It involves the preparation and processing of micro-thin copper foils which must maintain a highly uniform quality over millions of battery cells. Most of the equipment is from tier one providers from Japan and South Korea. Due to the highly automated character of the process, the workforce inside the cleanrooms is very small: mostly skilled or semi-skilled equipment operators and maintenance workers.

Packaging and the assembly of batteries occurs in facilities of different sizes according to production volumes and product characteristics. Cells are inserted into metal casings and frames, usually by medium-skilled assembly workers with some experience. In larger facilities this is done on assembly lines with some automation; smaller facilities mostly use manual assembly.

Electronics assembly (battery management systems) consists of the generic work processes of electronics manufacturing, i.e. the assembly of printed circuit boards, the manual assembly of certain non-standardised parts and enclosures, and final testing. According to volumes and product characteristics, this work is performed in facilities of different sizes, some of them being integrated in electronics factories with various other products.

Production of battery frames and casings occurs in specialised factories of different sizes and involves standard processes of metal manufacturing such as cutting, drilling, welding, etc. Production is becoming more and more automated; leading companies in the Greater Bay Area are using imported high-precision equipment and robots to improve production quality and save on labour costs.

Final assembly and configuration of car frames mostly occurs in the facilities of the carmakers who are using externally produced battery cells. Work organisation differs according to the products and the production models of the various carmakers. As has been explained above, the division of labour between carmakers and battery providers is still relatively unstable. The largest car factory in south China, a Chinese-European joint venture, has built a battery assembly plant on its campus where the batteries for the multinational's traditional car platform and models are configured. This process is relatively labour intensive, because platforms for combustion-engine vehicles are not suited to receive large Li-ion battery assemblies. With the transition to a specific platform for electric vehicles, standardisation and the modularisation of this process is expected with potentially fewer workers. Testing of the batteries requires extensive safety checks. Workers must undergo special training and certification which the company provides through its highly developed internal vocational training system.

In general, the work process in Li-ion battery manufacturing is relatively differentiated in its various stages and segments, but its basic characteristics are similar to industrial production familiar to the metal and electronics industries. Much of the existing knowledge on practices of decent work, workforce training and occupational health and safety can be applied to this field. For the core process of battery cell manufacturing, no viable studies exist regarding the chemical and toxic risks for workers. The existing Chinese and international literature on health hazards in battery manufacturing mostly deals only with traditional lead acid batteries.

According to our observations, working conditions and the workforce in the battery sector resembles those of other manufacturing industries such as electronics or automotive supply. The majority of workers are low to medium-skilled, paid according to the general local standard for wages in the Greater Bay Area (around 5000-6000 RMB per month (720-860 dollars) for lower-skilled and 6000-8000 (860-1150 dollars) for medium to higher-skilled assembly workers and equipment operators). Skilled maintenance workers are relatively few; maintenance and equipment calibration is mostly performed by engineers with college degrees.

As in the Greater Bay Area in general, most workers, including higher-skilled ones and engineers, have a migrant background from the rural areas of Guangdong or other provinces. Production workers are housed in dormitories, either on company premises or in rented facilities in industrial areas. Higher skilled workers live in apartments provided by companies or in private housing areas. Under the existing rules and regulations, migrant workers have no long-term residency in their cities of employment and have only limited access to social services, schools and government subsidies for housing, etc. Therefore, turnover among the local industrial workforce remains high, something which is also the case among higher-skilled employees, too.

4.5 Workers' rights and trade unions

In the broader context of the restructuring of the Chinese car industry, work regimes in battery manufacturing can be considered as one element of the 'Foxconnisation' of automotive manufacturing described above. Battery production and the related areas of electronics manufacturing have adopted indigenous Chinese regimes of high-performance production or flexible mass production familiar to electronics contract manufacturers. Only in the final assembly and configuration facilities that are connected to core carmakers and their joint ventures can it be assumed that working conditions and pay are at the level of established tier one car companies.

From this perspective, the battery sector reflects the divisions along the production chains of the automotive industry in China which have been analysed in the literature quoted in this chapter. Official trade unions have an established presence in the state-owned carmakers and their joint ventures, but they do not play a strong role in setting the standards of wages and working hours. Collective contracts and bargaining procedures only exist at company level and there are no industry-wide labour contracts or wage standards. However, wages and benefits at the state-owned carmakers are comparatively high, while automotive workers are among the highest paid industrial workers in China. In addition, the state-owned carmakers have comprehensive vocational training systems and internal labour markets. Wages and wage classifications are linked to workers' achievements in education and training.

Under the labour regimes prevalent among private carmakers and electronics firms, wages and benefits for production workers are much lower. Trade unions exist in most of the larger companies, but their position is still weaker than in the state-owned enterprises and joint ventures where the trade union is normally integrated into the management structure. As we have mentioned already, under the rapid expansion of the BEV sector in general, and battery manufacturing in particular, these conditions may rapidly become the 'new normal' in automotive manufacturing in China.

In general, employment in these companies represents low to medium standards of work and pay in China. Working conditions in foreign investment enterprises and joint ventures are significantly better; and these companies are seen as preferred employers by Chinese workers. On the other hand, conditions in the private Chinese companies in the car industry, such as BYD, Geely or the larger battery manufacturers, are significantly better than in the labour-intensive smaller and medium enterprises which represent the lower end of supply chains in the automotive and electronics industries.

Major labour conflicts or publicly known violations of (the rather low level of) workers' rights in the BEV and battery sectors could not be detected in the course of our research. In the respective locations in the Greater Bay Area and in other areas in China, several cases of the severe poisoning of workers in the production of traditional lead acid batteries did become known between 2005 and 2015. There are no such reports from Li-ion battery facilities or related electronics factories. We cannot say much about working conditions and wages in the mining, materials processing and recycling segments. Most of these facilities are located in rural mining districts in northern and central China, and one may assume similar conditions to coal and other mining industries.

In the particular case of the supplier firms cited above, automation is being used to compensate for the higher labour costs supported by the newly established collective bargaining system in these companies, although this is not part of an overall assault on workforces and their improved collective rights. Rather, cooperative labour relations based on 'moderated mobilisation' are what prevails (Yang et al. 2019). Workers are experiencing an intensification of work and stricter control, but they do not see their jobs as immediately threatened. However, they do expect higher wages and a fair share of the productivity gains and economic profits, as well as a more rational wage structure that would remunerate the skill improvements and greater effort required from them. Collective bargaining has, so far, not particularly addressed these topics and remains relatively weak due to its limitation to single factories. But there definitely remains room for qualitatively oriented bargaining strategies as well as for industry-wide bargaining at local level.

5. Conclusions

As we explained in Section 1 of this chapter, the automotive industry is undergoing a massive transformation that historically can be compared to the breaking-up of Fordist and neo-Fordist production models and the subsequent globalisation of major manufacturing industries in the 1980s and 1990s, electronics in particular, with vertical disintegration and re-integration at the heart of this process. The existing production systems of global carmakers and their hierarchical supplier pyramids (commonly known as the 'Toyota model') may, as a result, gradually lose their core role in the industry while new sources of production know-how are emerging, no longer exclusively controlled by traditional carmakers. Electric Li-ion batteries are a key element in this transformation.

Compared to the 1990s, the conditions of what we call 'globalisation' have changed considerably. Emerging economies have not only developed as low-cost production bases and 'extended work benches'; rather, they have accumulated substantial technological and production know-how at various stages and have become important players in global innovation. In the electric vehicles and battery sector, China is the global lead market, the major producer and a key innovator. Global supply chain development, therefore, is no longer a top-down process, controlled by the leading global brand name companies in industrialised countries, but multidimensional in the sense of distributed centres of innovation and industrial players controlling different segments. The global carmakers are no longer the undisputed leaders of industrial development in the automotive industry.

China caught the opportunities of impending disruptive transformation and has gained a leading position as a first mover in BEV battery manufacture. This development was based on a large sector of battery suppliers for consumer electronics, computers and mobile phones. China now has a complete Li-ion battery value chain for BEV, from upstream materials production to the midstream manufacturing of cells, modules, battery management systems and packaging, and to downstream applications in mobility and various other fields such as grid storage, lighting, solar energy and movable storage. Within the automotive industry, Chinese battery producers are becoming important players as providers of core components, reaching out into other battery technologies such as fuel cells.

The dominant strategy of Chinese firms can be described as specialised vertical integration across the industrial chain, including Li-ion battery cell production, raw materials mining and refining, cell materials and components, electronics assembly, packaging, the final assembly of electric cars and the building of charging stations. Major firms are expanding and integrating their activities into various stages of the production system, but vertical integration remains within the battery value chain and around the specialised field of battery or electricity storage. This ongoing recombination is securing a dominant role for Chinese firms in global production networks within the battery sector and within the production of electric cars in general.

In the environmental field, China has established a comprehensive framework of laws and regulations connected to national and regional industrial policies promoting BEV and green mobility. As we have explained, the industrial policies to upgrade BEV manufacturing have important effects on battery manufacture, both with regard to product safety and recycling. China's current effort to build a comprehensive system for BEV battery recycling is ambitious and advanced compared to similar efforts in developed industrial countries. One reason is that the unexplored negative environmental consequences of BEV-based mobility, such as rising electricity consumption, shortages of raw materials and growing electronic waste, have become more visible in China than elsewhere.

Reports about these and related problems have been rare and the potential environmental problems of BEV mass production are scarcely present in the Chinese mainstream media. However, there remain a number of open questions which should also be raised with major carmakers:

- the environmental impact of Li-ion battery manufacturing has not been systematically studied in major industrial countries, including China. Given the size and scope of the industry in China, a systematic review of environmental impact studies of battery plant location could give important insights in this field;
- the same can be said for recycling facilities and the environmental impact of materials mining and refining. Since these industry segments are mostly located in the rural and less developed regions of China, the impact on rural and environmental development should be studied, encompassing other developing countries;
- unregulated recycling facilities have been a problem in China. The government has recently promoted efforts to eliminate unregulated recycling and to stimulate recycling platforms. The question has to be raised how effective these policies are and whether battery manufacturers and recyclers are still using unregulated recycling facilities. On the other hand, new initiatives in this field, such as online trading platforms for used batteries, should be studied.

In the field of labour relations, the 'Foxconnisation' of automotive manufacturing through the rapidly growing BEV segment is bringing lower wage and employment standards to the Chinese automotive industry which has hitherto been dominated by state-owned enterprises and joint ventures. Whether this development will induce a general trend towards lower wages in core automotive manufacturing in China, or whether the existing segmentation of employment conditions between some tier one carmakers and the lower tiers of supplier networks will be increased, remains to be seen. Certainly, this will depend on the degree to which official trade unions and government labour bureaus are involved at local level and whether existing labour laws and standards are properly implemented.

The consequences for global supply chains may be different to the electronics industry, since the emerging BEV sector does not yet have a clear division of labour between technology-defining brand name firms (such as Apple, Dell or Huawei) and contract manufacturers (such as Foxconn). In addition, the motives to relocate factories and build global production networks lie not only in lowering labour costs but rather more in strategic considerations concerning market proximity, co-operation and co-innovation with end users, global carmakers in particular. Electronics contract manufacturers themselves are becoming important players in production networks for BEV, while they have substantial technological resources. Some have already established joint ventures with global carmakers in China, such as Foxconn with Stellantis.

The open questions in regard to the assessment of labour standards in the production regimes of major BEV firms and of global carmakers are mostly related to the general framework of labour relations in China. These include how companies comply with existing labour laws and health and safety regulations, whether they pay living wages and accept trade unions and collective bargaining regulation and how working conditions, occupational health and safety in particular, is developing in battery cell production.

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Chapter 4
Electrification and employment in the French automotive industry

Sebastian Schulze-Marmeling and Emmanuel Palliet

1. Introduction

The European automotive industry began its shift towards electric vehicles in 2020, at the point when the effects of the coronavirus crisis were hitting particularly hard. In France, its vulnerabilities are all the more visible: dependence on globalised supply chains; production overcapacity; and low competitiveness in the context of increased competition. The difficulties in the industry caused by (industrial) disinvestment – from which it has suffered for many years – and many waves of massive relocation to low-cost countries have now begun to stick out. This is bad news for employment with site closures and relocation piling up again. Moreover, France's delay in terms of the transition from the historically dominant internal combustion engine (ICE) to non-fossil fuel technologies is all the more glaring as the other European players are accelerating.

In 2020 for the first time, electric (EV) and plug-in hybrid (PHEV) vehicles had a market share in excess of 10 per cent in France and across Europe. Electric vehicle sales grew dynamically in both 2021 and 2022. By the first half of 2022, registrations of battery electric vehicles (BEV) in the EU reached a market share of 9.9 per cent while for PHEV 22.6 per cent. The development was particularly strong in Spain and France with double-digit gains in EV sales (+22.0% and +18.6% respectively) compared to the same period of 2021 (ACEA 2022).

Electric vehicles will most likely dominate sales within a few years. Regarding the evolution of battery prices, parity between the purchase price of electric vehicles and those powered by combustion engines can be expected within five to seven years (BloombergNEF and Transport & Environment 2021), reinforcing realism over the sooner rather than later end to the combustion engine. This parity has already been achieved if we consider the total cost of ownership (i.e. purchase plus use) (BEUC 2021).

Although the European standards on CO_2 vehicle emissions have been the driving force behind the shift towards electric models, they played a controversial role in de facto emissions reductions. By setting an average emissions ceiling of 95g CO_2/km by 2021, they have enabled a 36 per cent reduction in emissions between 2001 and 2020, as measured by the NEDC test cycle, whereas real drive emissions in the same period decreased by a mere 8 per cent (see Pardi, this volume).

Nevertheless, the vehicles placed on the market still emit too much CO_2 with regard to climate objectives, especially as the European Union has raised its overall 2030 objective of reducing greenhouse gas emissions for cars, taking it to a reduction of 55 per cent compared to 1990 levels and to zero emissions by 2035, and facilitating a path to total decarbonisation for the industry by 2050.

The end of the internal combustion engine is therefore coming much faster than the industry had anticipated, and it is bringing about unprecedented change in the industry. Europe's current effort to catch up, via the European Battery Alliance, is a key step not only in avoiding a possible lack of supply of battery cells but also in not losing the battle over electric vehicles, thus retaining the possibility of anchoring the car industry of tomorrow in Europe. To achieve this goal, the European car industry intends to spend almost 145 billion euros to convert its product portfolio by 2025 (Transport & Environment 2019). It does not seem excessively optimistic to conclude that electrification might not be a threat but actually an opportunity for the European industry. According to Transport & Environment, Germany, France, Spain, Italy and the UK will hold around 85 per cent of production capacity by 2025.

Nevertheless, the French industrial fabric is struggling to cope, a trend which has been observed for some time. The available data reveal the extent of the problem: the number of vehicles assembled in France has fallen from three million in the early 2000s to two million in 2019 and 1.3 million in 2020, at the height of the coronavirus crisis.

In addition to technological developments and changes in the global supply chain, the decline of the French automotive industry calls into question the economic policies that have been pursued over the past ten years in both France and Europe. At European level, in the absence of a coordinated industrial strategy, competition is increasing between countries to attract investment. Social dumping practices are fuelling relocations within the Union. Furthermore, the standards on CO_2 emissions from light vehicles are based on a set of rules which may turn out to be counterproductive. The weight-based standard is a case in point, disadvantaging the lightest vehicles and marking a lost battle for the French industry against that of its German neighbour.

At national level, the automotive industry has benefited from massive support from the French state for many years, from scrappage bonuses to the recovery plan initiated in 2020. However, despite the stated ambitions of modernising the production system ('Digital Factory' or 'Factory 4.0') and switching to electric vehicles, and in spite of the 8 billion euros put on the table in 2020, this plan does not alter the underlying trend of rationalisation and delocalisation and, therefore, of job losses. Consequently, it is crucial to analyse the technological changes fuelled by electrification in conjunction with other trends, such as European and national economic policy and globalised value chains.

The automobile industry is at a turning point in its history. The transition to electromobility is a key stage in maintaining and redeploying industrial activities and jobs in the long term, and in meeting the challenge of the total decarbonisation of transport by 2050. This chapter attempts to contribute to the debate over how public policy and company strategies can be leveraged to contribute to electromobility while impeding the further deindustrialisation of French and western European regions.

We start our analysis by presenting our data and methodology. To assess the scope of the development, we have compiled a unique database of employment information at company level. The dataset focuses on car engines and encompasses some 140 sites in all with roughly 70 000 jobs as of 2018. The data give a screenshot of the current situation of employment and allows us to track some of the more recent trends. To model scenarios for future developments, we have also conducted expert interviews to assess the impact of electrification on employment. Section 3 subsequently presents some insights from our database. Thereafter, we present the strategies being applied by industrial players (Section 4) followed by different scenarios for the future, ranging from 'laissez faire' to more ambitious goals for CO_2 reduction and strong industrial policy to protect local value chains and employment (Section 5). The chapter finishes with some concluding remarks.

2. Data and methodology

To conduct our analysis, we have compiled a unique and comprehensive database with information drawn at company level. The analysis presented here focuses on automotive powertrains as these are expected to experience the strongest impact of electrification. As a result, we have developed consolidated information on 114 sites and/or establishments in the engine industry in France (see Figure 1). In total, our database consists of a starting sample of 121 establishments (three sites closed during the study period).

Figure 1 **Automotive industry**

Powertrain sector

OEM
OES
Subcontractors

- **136 sites** in the powertrain industry
- **70 000 employees** (2018) in production, R&D and services

For each establishment, in addition to its company name and the group to which it belongs, we have collected some supplementary information:

– rank in the supply chain (original equipment manufacturer (OEM), original equipment supplier (OES), subcontractor);
– degree of exposure to the change in engine technology (from 1 to 4);
– family of activity;
– the professional categories employed at the site;
– the portfolio of activities and business lines (R&D, production, support functions).

Finally, we have assessed, to the extent that this was possible, whether the site is undergoing a diversification strategy.

The data collected by establishment are compiled from the social balance sheets (*bilan social*) produced by companies at different dates (2014, 2016 and 2018). In addition, we conducted interviews when access to documentary evidence was not possible. In a few cases, we extrapolated data from previous years or used public data provided by the company or drawn from other public sources.

The following data were collected:

- number of permanent employees;
- employment categories;
- average share of temporary workers;
- share of the workforce older than 55;
- employment forecasts or employment trends over three or five years.

A selection of this data is presented in Section 3.

3. Insights into the French automotive industry

Our database records almost 54 200 permanent jobs (excluding temporary workers) across the 121 sites (450 people on average). To this volume must be added the 8500 temporary jobs on the 70+ sites for which we have information; extrapolating this across the entire panel, we estimate that there are around 15 000 temporary workers, which amounts to a total employment in 2018 of 70 000 people.

Car manufacturers and equipment suppliers dominate this panel:

- 23 OEM sites account for half the workforce;
- half the sites are tier one suppliers, representing almost 40 per cent of jobs.

The database covers an estimated one-quarter of employment in the automotive industry in France. Although our information is not comprehensive, we may assume that our sample is a reliable indicator capable of producing representative results for the entire powertrain sector of the industry. In addition, the 35 subcontractor sites in our panel record nearly 8500 jobs so the above is probably an underestimate of the reality of the extent of activity in this sector. Most of these companies, however, have a diversified product and customer portfolio both within and outside the automotive industry so it seems difficult to link all the establishments of these players to the powertrain sector alone.

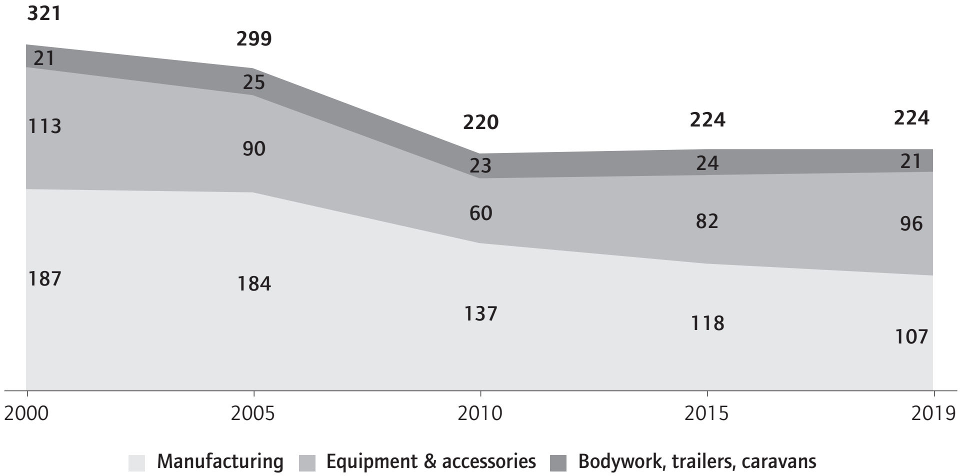
3.1 Employment trends

Compiling reliable data on employment in the automotive industry is a challenging task as the definition of its scope varies significantly. Le Comité des Constructeurs Français d'Automobiles (French Automobile Manufacturers Committee; CCFA), the industry association, encompasses a large range of services (such as driving schools, insurance companies and road transport) and its annual analysis comes to the conclusion that some 8-10 per cent of private sector employment is linked to the car industry

(CCFA 2021). Although these figures are often cited in the press and by politicians, most experts agree that they greatly overstate the importance of the industry.

Looking at the data in more detail, we observe a strong decline in automotive employment, especially in the first decade of the millennium, as Figure 2 shows. Jobs in manufacturing have continued to decrease over the entire period with, in the last 20 years, 42 per cent disappearing. In the equipment and accessories sector, however, the downward trend after 2000 has been turned around and the data record an increase. This trend is partly due to changes in the statistical definition of the scope of these activities from 2015 onwards but might also be explained by the increased outsourcing of the tasks that were not considered 'core business' by the OEMs.

Figure 2 **Employment in the French automotive industry, 2000-2019 (thousands)**



Source: CCFA, several years.

Syndex data drawn from our own database suggest that, over the last five years alone, employment in the industry has fallen by 7-8 per cent. Our findings contradict the CCFA figures regarding suppliers, most likely a consequence of a narrower definition in our database. The overall trend, however – that employment in the automotive manufacturing industry is showing a decreasing trend – is confirmed by both CCFA and Syndex data.

In contrast to elsewhere, economic recovery after the 2007-08 economic crisis has not been accompanied by a recovery in employment in the automotive industry. At the same time, due to its importance in the overall economic structure, developments in this industry have a major impact on others: it has been a major driver of the job reductions across the economy in recent years. These two factors contribute to the importance of any analysis of the future of employment in the industry and make an active steering through public policy all the more necessary.

The outlook for the coming years, however, provides no grounds for optimism. In its recent assessment, the Observatoire de la Métallurgie (2021) points to the risk of losing another 100 000 jobs by 2035 in the French automotive industry.

The switch to electric vehicles is the major factor in the transformation of business models, work and employment. The conversion to electric power which is now underway will have an impact on traditional activities and, in particular, on the production of engines which will require fewer mechanical parts and less manual labour.

To date, however, electromobility has opened new opportunities above all for those companies that anticipate, diversify and position themselves in a world that has become ultra-competitive. With, in 2019, only 4 per cent of vehicles produced being electric, and just two projects linked to the manufacture of batteries in France, the challenge today is to accelerate the first stage of the environmental transformation of mobility.

As of today, one of the main reasons for the drop in activity and employment are fundamental developments in the global supply chain. The automotive market, which is now entirely globalised, is no longer limited to the historical production zones, now fully integrating China, Morocco, Turkey and eastern Europe. The players in the industry have seized the opportunity to source strategically from low-cost countries, exacerbating competition between countries and accelerating relocation.

In recent years, the production of city cars and compact cars has lost its last productive ties to France. The Renault Clio, until recently produced in Flins, has now moved to production lines in Novo Mesto (Slovenia) and Bursa (Turkey), while the Peugeot 2008 has left Poissy and is now produced only in Trnava (Slovakia) and Kenitra (Morocco). France has relocated most of its industrial production to third countries (indeed, the most within the OECD), which explains the current situation to a significant extent. If, at the beginning of the 2000s, one out of every two cars sold on the market was manufactured in France, by 2020 it was one in every five.[1] Although the electric market is taking off, with some 10 000 registrations of 100 per cent electric vehicles recorded in April 2021, only 18 per cent are produced in France (CCFA 2021)).

Figure 3 shows that almost half the jobs (46 per cent) are with OEMs followed by tier one and tier two OESs (39 per cent) and subcontractors (15 per cent). OEMs also show a tendency to concentrate employment on a few large sites whereas jobs with suppliers are spread across smaller establishments.

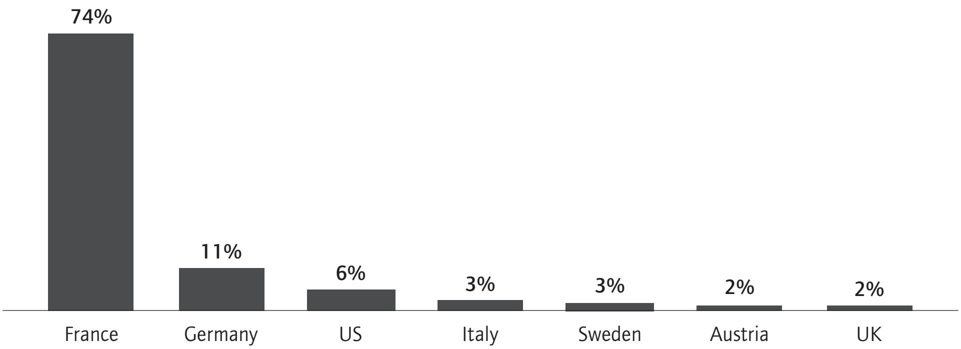
According to the analysis presented in Figure 4, three out of four jobs are within French-owned groups (74 per cent). Employment in foreign-owned companies is concentrated in German businesses (11 per cent) with all other countries showing lower rates of weight in the overall employment landscape.

1. The share of French brands in the registration of cars in France decreased slightly over this period. In 2000, 59.1 per cent of new light passenger vehicle registrations were from a French brand; in 2019, it was 56.8 per cent (CCFA 2021).

Figure 3 **Employment in the French automotive engine sector in 2018**

Source: Syndex database.

Figure 4 **Employment in the automotive engine sector by company country of origin**



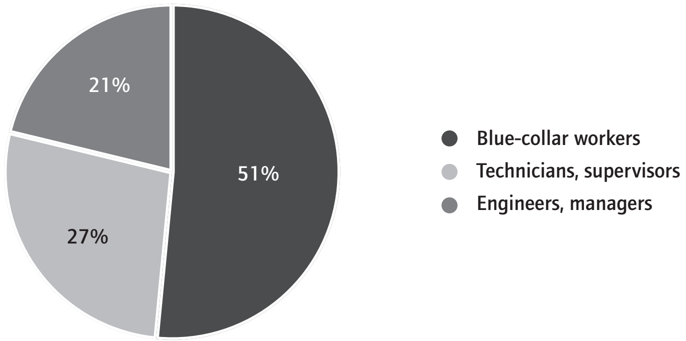
Source: Syndex database.

3.2 Job profiles and age structure

Blue collar workers represent 51 per cent of employment in the industry (see Figure 5). Service activities (support functions, administration, trade) and R&D contribute to employment figures for technicians, supervisors and administrative staff (27 per cent) and for engineers and managers (22 per cent).

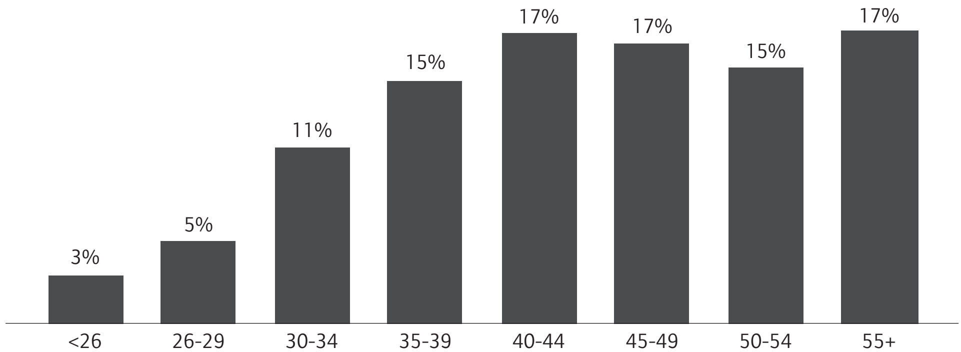
The workforce in the sector is relatively old, as shown in Figure 6. The 55+ age group is among the largest categories of employees (17 per cent) and almost half the workforce is over 45. The age structure poses different challenges for the profound restructuring process that is inevitably linked to electrification. Whereas the high share of older workers provides some reserve for workforce restructuring via the use of early retirement instruments, the very low share of younger age groups (up to 34) on the other hand poses a serious challenge in respect of skills development.

Figure 5 **Job profiles**



Source: Syndex database.

Figure 6 **Age structure**



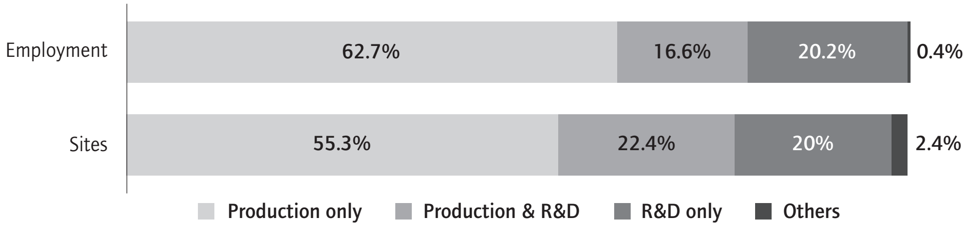
Source: Syndex database.

3.3 The value chain

Our panel consists of various parts of the supply chain within powertrain and drivetrain (transmission) activities, with activities related to exhaust and pollution control, and electronics and engine control.

Figure 7 shows the number of sites and employment by site profile. Some 20 per cent are pure R&D sites (20 per cent of employment) and another 22 per cent have both R&D and production capabilities (17 per cent of employment). However, more than half of all establishments (55 per cent), representing close to two-thirds of employment (63 per cent), are exclusively dedicated to production. We believe that pure production sites are more exposed to European or international competition and that it is more challenging to reorient their mode of production to new product lines. Therefore, we assume that these sites are more at risk than R&D centres or mixed establishments.

Figure 7 **Site profiles**



Source: Syndex database.

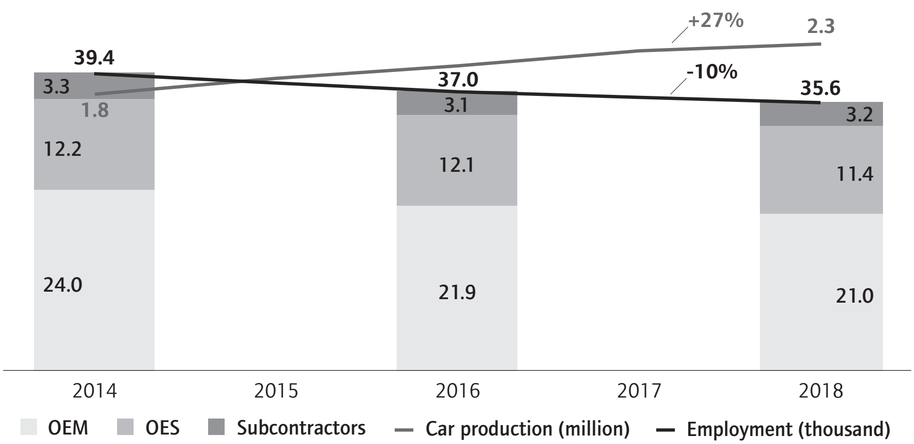
3.4 Workforce structure and job quality

For more than half the sites (and workforce), we can follow the trends in employment over the period 2014-18. It is worth noting that this period recorded a significant rebound in economic activity as well as a growth in volumes, and that this was actually accompanied by a drop in employment. While automotive production in France in this period increased by 27 per cent, employment in the industry fell by 10 per cent, as Figure 8 shows. We can also observe that:

– the decline was stronger amongst OEMs (12 per cent);
– for suppliers, the downward trend was not as strong as for manufacturers (6 per cent for OESs and 4 per cent for subcontractors).

Figure 8 also shows that regular forms of employment (i.e. with a permanent contract) suffered most of the decrease even at a time of expanding production.

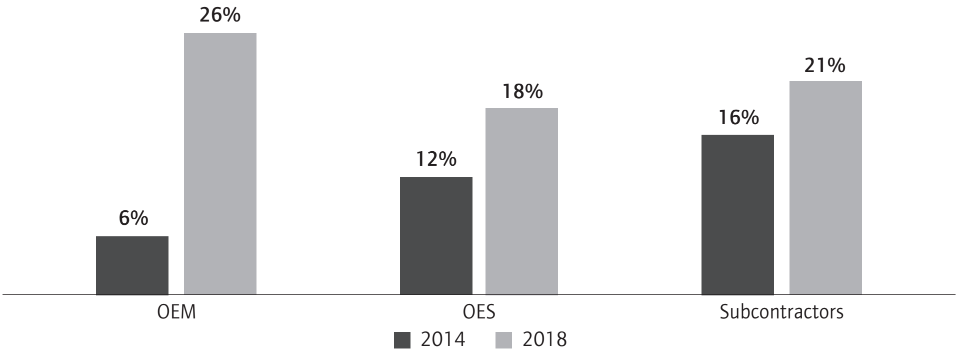
Figure 8 **Automotive production and permanent employment**



Source: Syndex database.

At the same time, the data show a high and rising level of agency work. According to Figure 9, the proportion of agency workers in the overall workforce has increased significantly. This is particularly the case among OEMs, where the share of employees employed with an agency rose to 26 per cent. For OES and subcontractors, the increase was less pronounced but remains substantial.

Figure 9 **Proportion of agency workers**



Source: Syndex database.

In conjunction with the figures on production and permanent employment, these data suggest that companies in the automotive industry used temporary workers to replace permanent employment during the recent upswing. We might thus conclude that the rationale behind this strategic choice was the perspective of electrification and the anticipation of a drop in the need for labour.

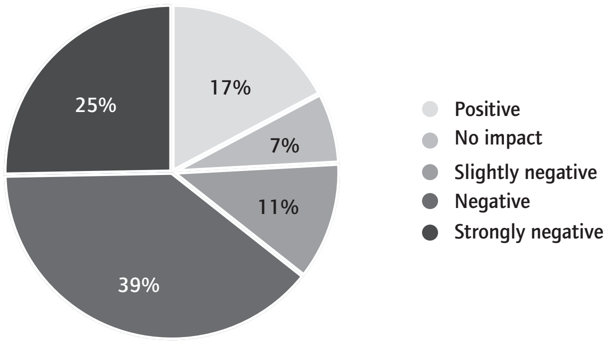
3.5 Summary of employment trends and short term outlook

As argued above, the decline in ICE technology and the gradual shift towards electrification will most likely have a differing impact on employment depending on the activity of the establishment. We note that 20 per cent of sites and employees are diesel-oriented and almost half in each case are within the field of thermal combustion. Nearly 20 per cent of sites (and 30 per cent of jobs) also make parts for EVs, however, but only 14 per cent of sites (and merely 5 per cent of jobs) work primarily on electric vehicles.

Based on our survey of sites, we estimate (see Figure 10) that more than one-quarter of the sites in the scope of our study are likely to see a strong impact from changes in the technology mix, particularly those which are specialised towards combustion engines. Half of these sites are beginning to diversify, particularly towards hybridisation or electric vehicles, but these are mainly manufacturer sites or large equipment suppliers. The sites that are expected to be affected (either strongly, moderately or weakly) are those which are focused on thermal combustion; we found that these are slightly more involved in diversification.

About fifteen sites (including those focused on EVs) view electrification as an opportunity. Many of these are manufacturers or equipment suppliers.

Figure 10 **Expected impact of electrification**



Source: Syndex database.

An outlook for employment trends over a three-year horizon was provided for more than 80 sites as regards whether the workforce was expected to increase, decrease or stabilise. These trends are rarely specified by the management of the establishments (only one-third produce a quantified evaluation of employment) and eight sites declared that they had no information at all. We have very little data on a four to five-year timeframe; most of the strategies being formulated only for three years.

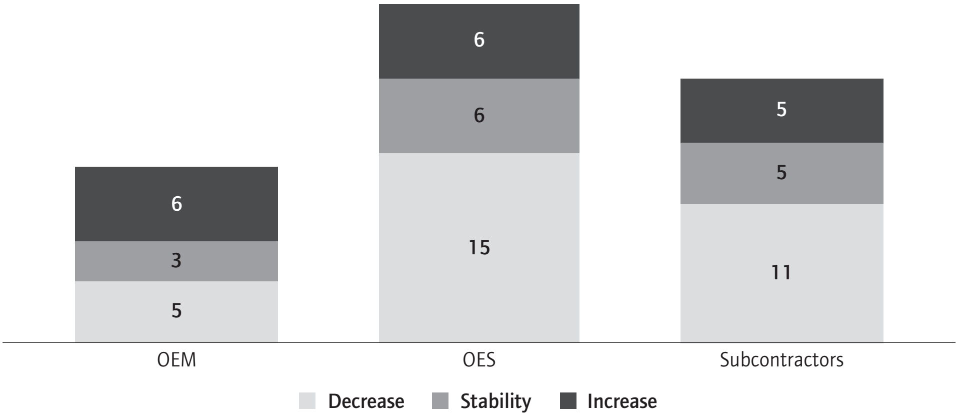
In a majority of cases, trends (even in the short term, excluding the Covid-19 effect) tend to be downwards (half the sites), probably significantly so for one-third of sites (and jobs) while positive for one-quarter (Figure 11). In spite of these trends, more than twenty sites, representing more than 11 000 jobs, see opportunities. While these sites include those already positioned towards electric vehicles, they represent different families of activities (and some are currently focused on diesel). The vast majority are diversifying, taking into account the evolution of the engine mix to come.

Out of the sixty two sites for which a qualitative assessment of employment trends is possible, some conclusions may be drawn:

- the evolution of the technological changes to the engine is the major factor, having a strong negative impact;
- on the other hand, the evolution of the product is perceived as an opportunity for roughly one-quarter of sites (for instance, diversification towards niche products for electric vehicles);
- productivity effects are certainly a factor, but they are rarely considered as the primary driver for the evolution of employment, whether it is about productivity developments within business as usual (three sites with a downward trend) or productivity gains as a result of the introduction of Industry 4.0 and automation (four sites);

– other factors are sometimes mentioned, such as the financial situation which is already giving rise to fears of negative developments across several sites.

Figure 11 **Expected employment developments at different production sites (number of sites)**



Source: Syndex database.

4. The strategies of the players in the automotive industry

The strategies adopted by car companies in the context of the transition to electrification are often based on a re-internalisation[2] of the design and production of automotive systems and components (including, but not limited to, batteries) or, alternatively, they are being achieved through new partnerships. For instance, we note that the Renault-Nissan-Mitsubishi Alliance and most German OEMs are embarked on internalisation whereas PSA (now Stellantis) is focused on building new partnerships (such as the joint venture with Saft to build two lithium-ion battery cell plants in Europe).

In terms of product strategies, our analysis shows the following trends:

– a growing number of automotive contractors are diversifying into activities linked to electric propulsion systems;
– for activities that have little or no link to the core business, such as batteries, partnerships are the option of choice;
– diversification makes it generally possible to maintain employment, or at least to limit its decline.

However, product strategy is not the only factor having an impact on employment. Companies are leveraging many other competitive angles some of which, including (de)location, (re)organisation or automation, are quite well-known. These modify both their presence in France and the productivity of production lines.

2. The terms re-integration and re-internalisation are used interchangeably and refer to the strategic decision to allocate development and production to internal capacities that have previously been subcontracted to an external supplier. Diversification describes the process of looking for new business opportunities.

4.1 The search for diversification as an alternative to the decline of the internal combustion engine

According to the responses recorded in our database of 75 sites, only one-quarter are not diversifying at all. Even among those companies that have launched significant diversification plans, it is unlikely that this will transform the face of the company overnight. Diversification is consequently often only partial, touching upon a fraction of the site's activities. For about thirty sites, we could clearly identify the nature of their diversification projects, most of which concern hybridisation (including 48V) and electronics. Whenever an estimate was possible, half the sites would only be diversifying up to one-quarter of their activity while less than 25 per cent of all establishments would be launching new activities for more than half their previous endeavours.

4.2 How are sites preparing for change?

The evolution of the engine mix and its probable negative impact on employment in the sector is not new; indeed, the present study is a fruit of this ongoing debate.

Efforts made by the French legislature are aimed at forging a broad alliance for the transformation in which social partners are certainly a key stakeholder. According to French labour law, employee representatives should have extensive access to so-called forward-looking employment and skills management (GPEC) strategies in respect of which the legislation stipulates the negotiation of agreements – in particular at company level. Moreover, French works councils are entitled to receive access to comprehensive information on company strategy as well as social and economic data (through, among other things, the right to name their own experts and consultants, and to receive from the employer a socio-economic database, or BDES).

In terms of measures, all the available evidence suggests that training will play a key role in preparing for electrification. The main findings from our research include the following:

- in general terms, training efforts are difficult to measure (especially given the reforms of recent years). It is difficult to say whether training is technical (rather than just mandatory and safety-related) or whether it is fit to prepare employees for the change in job requirements;
- only six of these thirty sites have a multi-year training plan (in the majority of cases, we do not have any information on training strategy);
- moreover, we know that the challenges of changing jobs and skills are significant in the context of 20 per cent of the workforce (at these 30 sites) being over 55.

Therefore, it remains to be seen to what extent the efforts being made by employers today will be sufficient to meet all the skill requirements of electrification. Anecdotal evidence suggests that some skill sets are already in shortage on the labour market (mostly related to electronic and/or mechatronic skills). Making sure that the present and future workforce is properly trained will be a key success factor in maintaining employment in the car industry, both in France and beyond.

4.3 New activities

In the landscape of the French automotive industry, which has been well-established for decades and is reliant on a century-old technology that it has never stopped developing, new activities are emerging, supported by the transition to electric vehicles. Some prominent examples are discussed in the remainder of this section, among which the highlights are as follows:

- EV batteries will lie at the heart of future electric powertrains. EV batteries concentrate most of the challenges represented by this new technology and they capture most of its value. To date, however, only a few industrial prototype units are active in France and large-scale industrial projects have yet to materialise. Two projects have been the subject of company communication since the start of our study: that of PSA with Saft in Douvrin; and that of Renault with Envision in Douais. Verkor has also communicated its intention to set up a factory in the near future;
- the recycling of EV batteries is an activity that has yet to be developed, but the sector has significant potential as the number of electric vehicles grows. For the time being, there are only a very limited number of players, including SNAM, Recupyl, Véolia and Umicor. We present an example of the Renault 'Re-Factory' below, which has integrated battery recycling into its business model;
- the retrofitting of ICE vehicles (ICEVs) is a niche and probably transitory activity involving the conversion of ICEVs to electric ones. There are some recent initiatives in France, one of which is also discussed below. This activity could contribute to accelerating the electrification of the fleet by producing a modest, but real, benefit in employment in automotive services;
- the development of mobility solutions based on hydrogen has been vigorously relaunched thanks to the hydrogen plans of the French government and the European Union. This technological vision is expected to deliver tangible results in a second phase (beyond 2030) and prerequires significant advancements in research and development as well as in the provision of infrastructure in the energy industry. The production criteria for hydrogen must envisage a process that is green and carbon neutral. To date, the majority of examples that use hydrogen have been identified in the transport sector: freight; public transport; road; sea; and rail. The hydrogen distribution network needs to be set up and the limited resources available should be reserved for efficient use. This technological solution does not seem to be suitable for individual mobility in the medium term, but there might be spillover effects with the automotive industry, with a possible impact on employment;
- recharging infrastructure: the development of electromobility implies the development of a network of recharging stations. The construction of this network of recharging points should involve the construction companies responsible for building these points as well as electrical installers. However, these are modest

projects in relation to the sector's current level of activity and employment potential seems limited.

This non-comprehensive list of alternative projects and diversification initiatives shows that an assessment of the full impact of the transition is challenging. It remains to be seen to what extent the current industrial infrastructure can be dedicated to such new tasks. An overall assessment of the employment impact of such initiatives goes beyond the scope of our study but, for illustrative purposes, we present a case study from the automotive industry in the next section.

Case study: the Renault 're-factory' in Flins

The pace of the electrification of the car in France and elsewhere remains largely hypothetical and so does the impact on employment. We can, however, observe some initiatives that might illustrate how plants that have been focused on thermal combustion engines in the past are trying to innovate their business model to prepare for the changes to come. An interesting case in point is the Renault site in the town of Flins.

Established in 1952, the Flins plant is located in the north-west of the region of Greater Paris. Current production includes assembly, parts (sheet metal and deep drawing) and some remanufacturing and refurbishment. In 2020, the plant produced some 93 000 Renault Zoe EVs and 36 000 Nissan Micras. According to public data, it employs roughly 2450 permanent staff and 1500 agency workers.

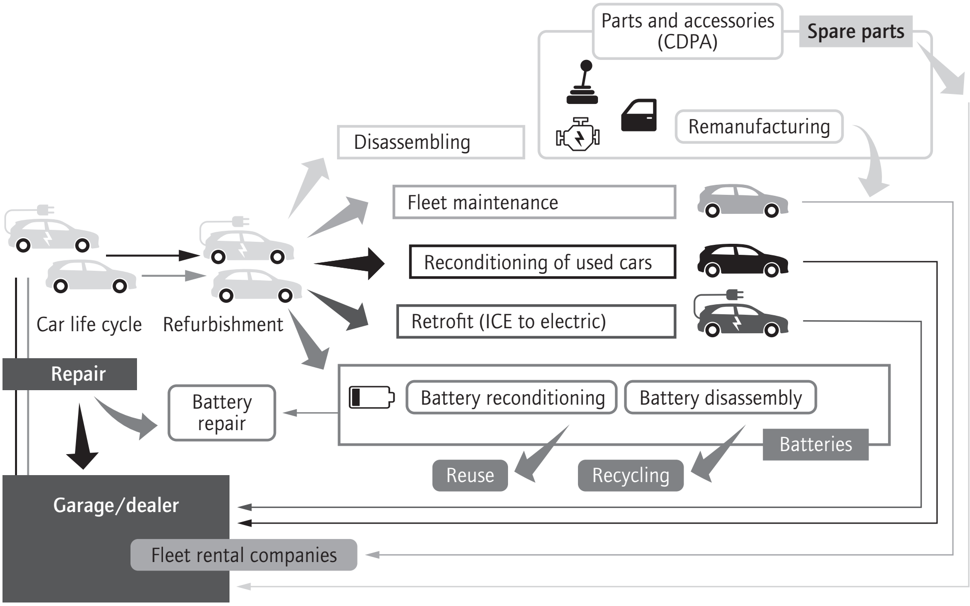
To understand the rationale behind the transformation of the plant to a 'Re-Factory', it is worth revisiting some of the general market trends that have inspired the project:

– although the European car market grew up to 2019, it flatlined thereafter and is unlikely to continue its pre-Covid trajectory of constant growth. Recent IHS MarkIt data suggest that, after recovery from the exceptional effects related to the pandemic, sales will level at around 18 million cars per year. Other factors, such as the current shortage of semiconductors and the disruptions in supply and sales because of the war in Ukraine, will most likely slow down the recovery;
– moreover, the demand for cheaper segment A and B cars has dropped over the last decade and there is a strong trend towards the higher price segments;
– at the same time, and related to these two trends, prices for spare parts have recorded a significant spike in the last few years. In light of the recent supply bottlenecks of new cars, this rise in prices is likely to continue.

In this context, Renault management launched the transformation of the Flins plant into a 'Re-Factory'. All assembly activities are scheduled to stop by 2024 and, instead, new capacities will be developed to offer a wide range of services throughout the life cycle of the car. Figure 12 summarises the concept.

The site will offer repair services for used cars, both ICE and electric. This line of business includes life cycle management for batteries. According to their condition, used batteries are either reconditioned to be reused or disassembled for recycling.

Figure 12 **Business activities of Renault's 'Re-Factory' in Flins**



Source: Public company information; chart by Syndex.

Refurbishment includes a wide range of services:

– disassembly: according to their condition, used cars might be disassembled with the spare parts put either for resale or to other refurbishment activities;
– fleet maintenance: the offer includes fleet maintenance services, namely for car rental companies, and other car fleet management services;
– moreover, the site will offer to recondition or even retrofit used cars (ICE to electric).

The company considers the activities to be strongly complementary. For instance, spare parts from disassembly might be used for repair or fleet maintenance activities, reconditioned batteries for retrofitted cars, etc.

The new projects were launched in autumn 2021 with the declared goal of reconditioning 180 used cars per day, or 45 000 each year. The company expects an annual turnover from these new activities of 200 million euros in 2025 and one billion euros in 2030.

Employment in the new 'Re-Factory' activities is expected to compensate in part for the stopping of production. In 2021, the site employed some 4000 people, more than one-third of whom were agency workers. By 2030, employment should stand at 3000 workers, with 2500 engaged in 'Re-Factory' activities and a further 500 in parts manufacturing. Renault management has recently announced that a similar model is under contemplation for the Sevilla plant in Spain.

5. Scenarios for future developments

In addition to the employment database, we have conducted expert interviews to establish how employment might develop with progress in electrification. Based on these interviews, we have set up employment indices that capture the need for labour according to the type of engine employed (diesel, petrol, light hybrid, plug-in hybrid, electric vehicle, fuel cell vehicle, gas vehicle). These indices were constructed by cross-referencing employment data with the volumes produced in seven segments of the engine industry:

- production of EV battery cells;
- engine components (machined parts of the engine block, including the injection system);
- electronics (electronic control units and sensors);
- engine assembly (final assembly of the engine);
- transmission and gearboxes (production and assembly of transmission and gearbox components);
- exhaust systems (production and assembly of exhaust system components, including pollution control);
- foundry.

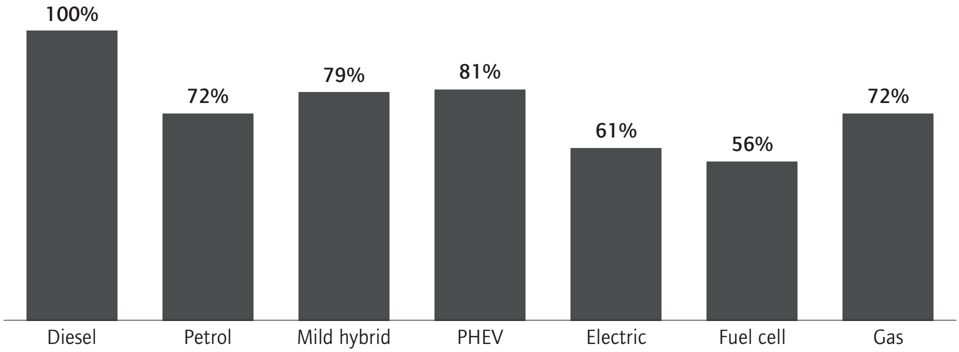
The indices take into account the reality of employment in the motor industry in France for each of these segments of activity and are expressed as the labour required, in full-time equivalence, to build 1000 units of vehicles. When compiling the dataset, battery cell production did not yet exist in France, so the employment index here is based on the assumption that the entire value chain for the assembly of electric global modular platform (GMP) packs is located in France.

The indices for fuel cell engines are estimated on the basis of technical considerations from other engine technologies. A significant part of the powertrain is similar to that of an electric vehicle with the difference between the two concentrated on the substitution of the EV battery by a fuel cell.

The estimated employment indices for each engine composition relative to the labour input needed for diesel engine technology – the most common ICE produced in France – are presented in Figure 13. Comparing electric engines to diesel, the overall need for labour for an electric engine stands at about 60 per cent. In terms of segments, the strongest negative impact is expected from assembly and components (especially mechanical pieces) followed by exhaust systems, transmission and gearboxes, and foundry activities. New jobs in battery production do not compensate for the losses elsewhere.

For the employment forecasts that arise from our scenarios, we have applied these indices to the motor production database according to the mix and volume defined in each one. The result is a calculation of employment that we can break down by segment.

Figure 13 **Employment indices by propulsion technology (diesel = 100)**



Source: Syndex database.

To build our predictive models, we have constructed five variables:

- volume (number of new cars and thus engines produced per year);
- the end of the internal combustion engine (year);
- the energy mix of newly registered cars;
- battery production in France;
- local supply chains.

These five variables are modelled according to two dimensions – volume development and strategic political choices. As a result, we have derived four base scenarios for 2050 staring from 2019 levels. Scenarios 3 and 4 are presented in two different variants so that there are six scenarios in total. The specifications of the models are detailed in the annex (Table 1).

The different assumptions of the models are subsequently applied to our database on engine production in France to predict future volumes. The employment indices presented above are used to estimate the employment effect of each predicted volume level and composition. Excluding parts of the data that are not relevant to our analysis, the base figure for all simulations is derived from our employment database and represents 57 815 direct or temporary employees in production functions (excluding R&D and support tasks).

The following subsection provides the results of each scenario. In each case, we first present the predicted engine mix and volumes that result from our simulations. Thereafter, the figures show the anticipated impact on employment on the basis of our employment indices. At the end of each scenario, a summary figure depicts the main factors driving the development.

5.1 Scenarios

Scenario 1: Further deindustrialisation ('laissez faire')

The evolution of the motor mix in this scenario is based on the following assumptions:

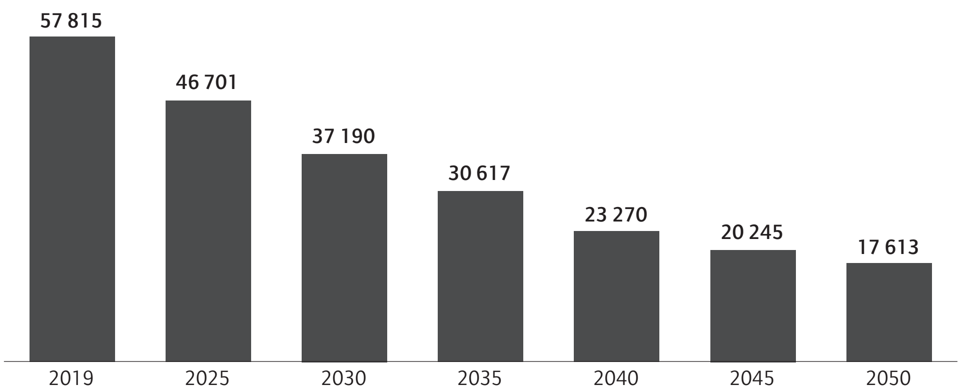
– electrification evolving at a relatively slow pace[3], reaching 80 per cent in 2040, while 20 per cent is made up of fuel cell engines;
– combustion engines exiting the market by 2040.

The evolution of production volumes in France would follow the path of deindustrialisation, with engine production reaching 1.36 million engines in 2050 (a drop of 55 per cent compared to 2019).

By applying our employment indices to these forecast volumes, the employment impact suggests that the decrease in employment would continue, leading to a loss of approximatively 40 000 jobs to reach 17 613 in 2050 (a drop of 70 per cent), as Figure 14 shows.

The creation of jobs related to the production of cells for EV batteries is limited to the equivalent of 51.4 gigawatts (GW) per year in 2050 (an estimated 5500 jobs by 2050).

Figure 14 **Scenario 1: Employment effect summary**



Source: Syndex database.

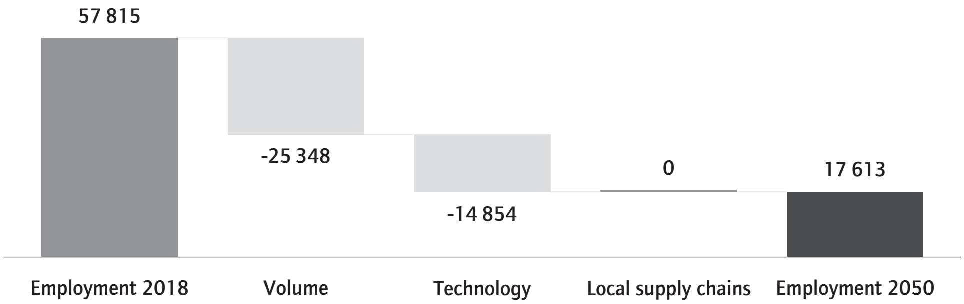
In Scenario 1, the employment trends are driven by two factors, as Figure 15 shows:

– a strong deindustrialisation effect, linked to the significant drop in the volumes of engines produced in France;
– an electrification effect caused by the lower need for labour in the production of electric vehicles.

3. Used as a baseline, given the adoption of the EU 'Fit for 55' package targeting zero emissions for EU manufactured cars by 2035.

It is worth noting that this scenario is based on a 'laissez faire' approach with no significant changes in public policies towards green mobility or company strategies regarding local value chains.

Figure 15 **Scenario 1: Drivers of employment change**



Source: Syndex database.

Scenario 2: Economic upturn

The evolution of the motor mix in this scenario is based on the following assumptions:

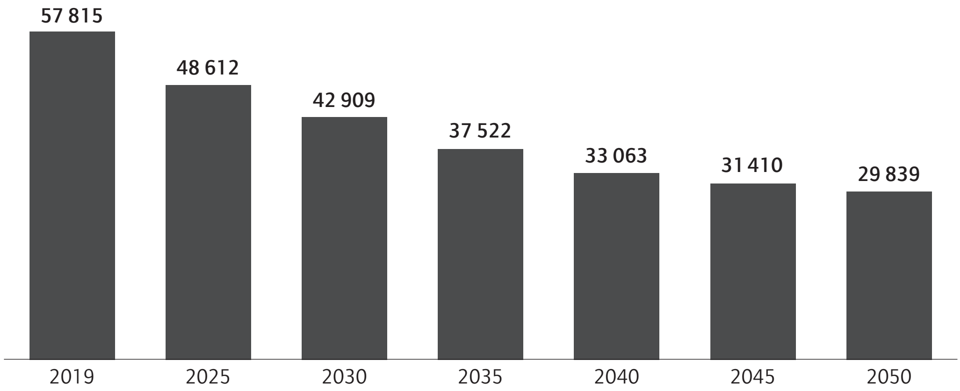
- electrification evolving at a moderately sustained rate, reaching 100 per cent in 2040;
- an end date for the sale of combustion engines of 2035 and one of 2040 for hybrid engines, whether rechargeable or not.

Here, production volumes in France are set to reach 2.26 million engines in 2050, a decrease of 25 per cent compared to 2019. By applying our employment indices to these forecast volumes, our data suggest that the decline in employment would also be significant, leading to a loss of roughly 28 000 jobs by 2050 (48 per cent), as shown in Figure 16. However, the development would be less severe than that predicted in scenario 1.

The creation of jobs related to the production of battery cells is limited to a need equivalent to 113 GW per year from 2040 (11 300 jobs).

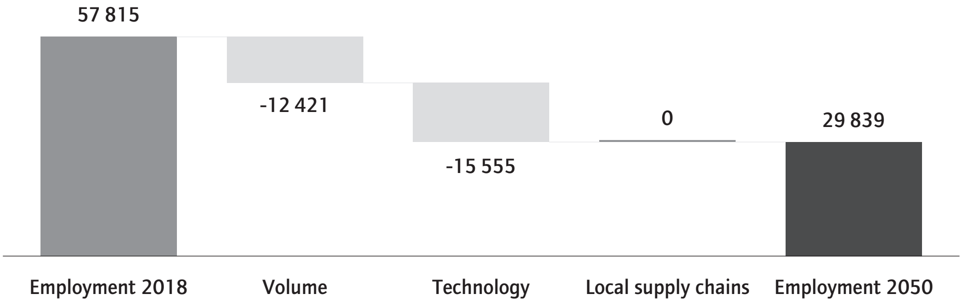
As regards the drivers of employment change (Figure 17), the overall dynamic is similar to that of scenario 1 (deindustrialisation and a drop in volumes), albeit with a lesser impact.

Figure 16 **Scenario 2: Employment forecast**



Source: Syndex database.

Figure 17 **Scenario 2: Drivers of employment change**



Source: Syndex database.

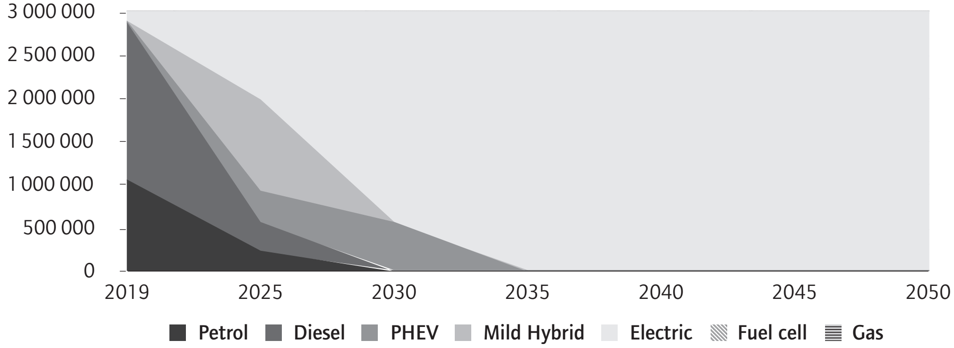
Scenario 3.1: Industrial relaunch

The evolution of the motor mix in this scenario is based on the following assumptions:

- electrification evolving at a steady pace, reaching 100 per cent in 2035;
- an exit date for combustion engines and non-rechargeable hybrids of 2030 and one of 2035 for PHEVs;
- the development of production volumes in France is maintained, i.e. an annual production of three million engines in 2050.

French motor production under this scenario is predicted to develop as depicted in Figure 18.

Figure 18 **Scenario 3.1: Forecast development of engine volume**



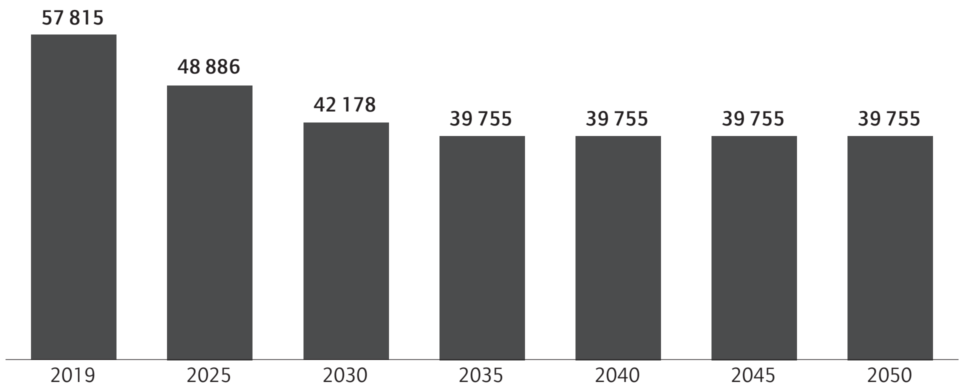
Source: Syndex database.

According to our forecasts, there would be a sharp decline in employment between 2019 and 2030, leading to a loss of 15 000 jobs (27 per cent) over the decade, as Figure 19 shows. The need for labour then stabilises, standing at approximatively 40 000 by 2050, a reduction of 18 000 compared to 2019.

The creation of jobs related to the production of battery cells reaches its maximum, based on a need equivalent to 150 GW per year, from 2035 (15 000 jobs).

With French motor production being stable over the entire period under study, only technological changes have an impact on employment.

Figure 19 **Scenario 3.1: Employment forecast**



Source: Syndex database.

Scenario 3.2: Industrial relaunch with local value chains

The evolution of the motor mix in this scenario is based on the same assumptions as in scenario 3 described above, namely:

- electrification evolving at a steady pace, reaching 100 per cent in 2035;
- an exit date for combustion engines and non-rechargeable hybrids of 2030 and one of 2035 for PHEVs.

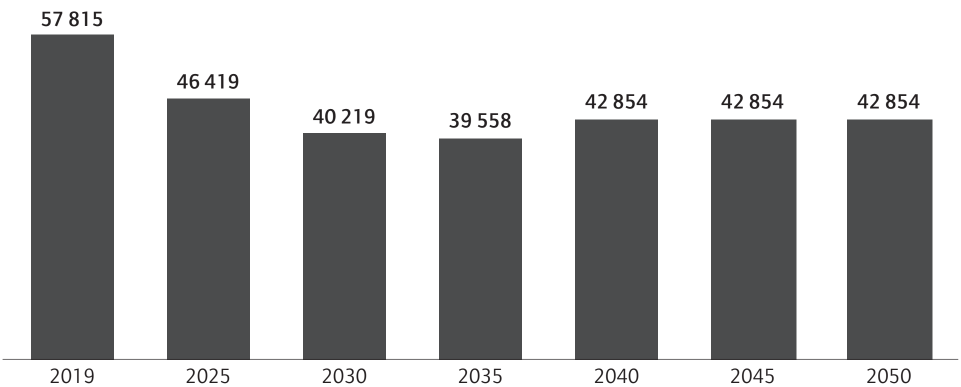
The main difference in scenario 3.2 is a drop in engine volumes to 2.5 million by 2030 (17 per cent) but that this stabilises thereafter. Moreover, we assume an additional 30 per cent of volume (excluding batteries) as a result of backshoring to promote local value chains.

Our estimates show that, as in Scenario 3.1, the decline in employment would be strong between 2019 and 2030, leading to a loss of 17 000 employees (30 per cent) over the decade, as Figure 20 shows. In contrast to Scenario 3.1, however, the need for labour would then recover, supported by the movement to relocate part of component production (of all types) for powertrains to local value chains.

The hypothesis adopted here is as follows:

- for electrical powertrain products, we assume that manufacturers/equipment suppliers will allocate a larger share of production to their French sites in their volume allocation decisions;
- this relocation of volumes applies to all component or equipment production activities (mechanical, electrical, electronic), but not to final assembly;
- therefore, the aim would be to strengthen ‘local integration’ (i.e. the local share of the production of the components involved in the final assembly of the engine);
- the local integration rate of the automotive industry is estimated at between 30 per cent (according to official sources) and 40 per cent (according to OEMs). There are no reliable estimates for engine production;
- in order to simulate an increase in this rate, we have applied a growth rate to the volumes of components produced in France. This growth rate only applies to electric engines. For the purpose of our computations, this rate is 5 per cent in 2025, 15 per cent in 2030, 20 per cent in 2035 and 30 per cent beyond then.

Figure 20 **Scenario 3.2: Employment forecast**



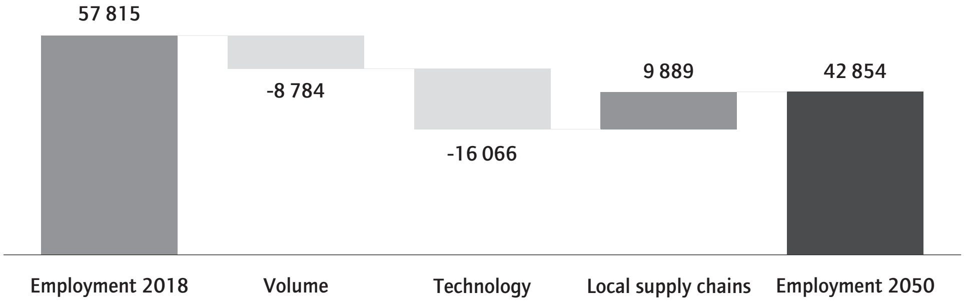
Source: Syndex database.

The drivers of employment change under this scenario are summed up in Figure 21.

The creation of jobs as a result of the production of battery cells would be equivalent to a need for 125 GW per year from 2045 (12 500 jobs). The retrofitting of ICEVs might increase the need for cells beyond this capacity between 2035 and 2045.

The increase in the local integration rate of the engine supply chain more than compensates for the decrease in the volume of engines assembled in France over the first decade.

Figure 21 **Scenario 3.2: Drivers of employment change**



Source: Syndex database.

Scenario 4.1: Industrial relaunch with local value chains and the end of the internal combustion engine by 2035

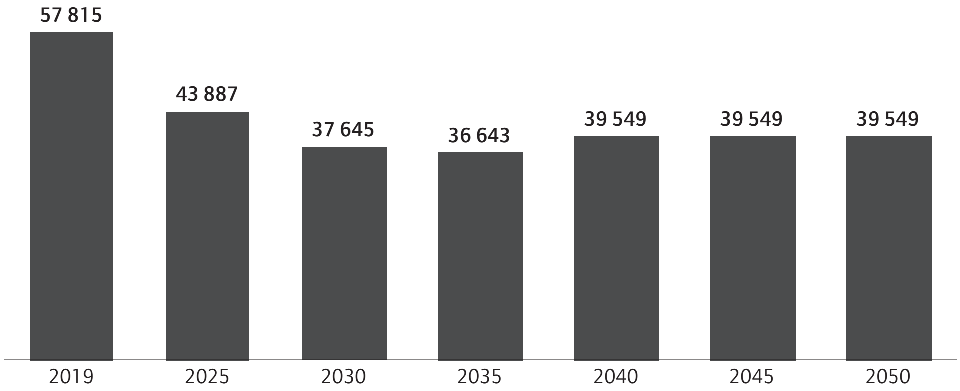
To calculate Scenario 4.1, we have made the following assumptions:

- electrification evolving at a steady pace, reaching 90 per cent EVs and 10 per cent PHEVs in 2035;
- an end date for the sale of ICEVs and non-rechargeable hybrids of 2030 and one of 2035 for PHEVs.

Accordingly, by 2030 the production level would go down to 2.33 million engines per year (a drop of 23 per cent compared to 2019) and remain at that level until 2050.

The employment simulation shows a decline in employment which would be most pronounced between 2019 and 2030, leading to a loss of 14 000 jobs (24 per cent) over the decade, as Figure 22 shows. Hence, the decline is weaker in this scenario than in all the others, some of the drop being deferred to 2035 and beyond, after the end of the sale of ICEVs. The need for labour then picks up as a result of the move to relocate part of component production for powertrains to local value chains, as above.

Figure 22 **Scenario 4.1: Employment forecast**



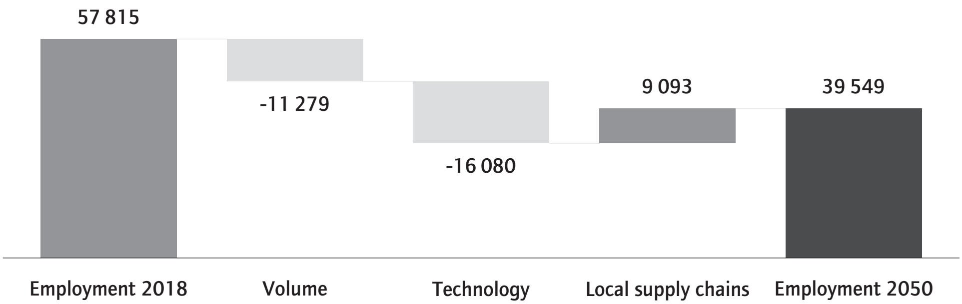
Source: Syndex database.

The main drivers of employment change under this scenario are presented in Figure 23.

The creation of jobs linked to the production of cells for batteries is based on an annual production in France of cells for a total of 94 GW per year from 2035 (10 000 jobs). The retrofitting of ICEVs constitutes a complementary outlet for battery cells; this would require additional capacity between 2035 and 2045.

As in scenario 3.2, the increase in the rate of local integration of the supply chain helps to compensate for part of the drop in the volume of engines assembled in France observed over the first decade.

Figure 23 **Scenario 4.1: Drivers of employment change**



Source: Syndex database.

Scenario 4.2: Industrial relaunch with local value chains and the end of the internal combustion engine by 2030

The evolution of the motor mix in this scenario is based on the following parameters:

- electrification evolving at a steady pace and reaching 80 per cent EVs in 2030;
- a market exit for combustion engines and non-rechargeable hybrids by 2030, and 2035 for PHEVs.

As in the previous scenario, production volumes in France are expected to record 2.33 million engines over the 2030-2050 period. In consequence, employment would drop sharply between 2019 and 2030, leading to a loss of 20 000 jobs (34 per cent). Thereafter, the need for labour would stabilise and later recover, driven by the backshoring of 30 per cent of powertrain component production (all types), as before.

As for battery cells, we would expect the equivalent of 94 GW per year from 2035. Again, the retrofitting of ICEVs would increase the need for cells beyond this capacity between 2035 and 2045.

The increase in the rate of local integration of the supply chain would, as above, help to compensate for part of the drop in the volume of engines assembled in France observed over the first decade.

5.2 Summary of the scenarios

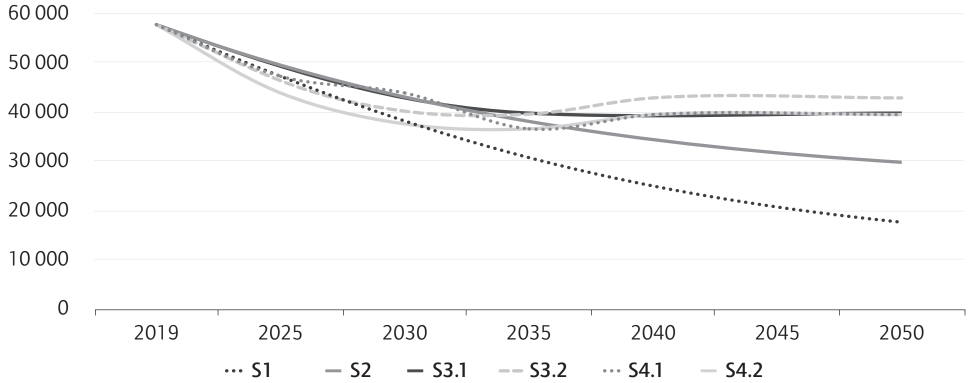
Figure 24 presents a summary of these six scenarios for employment in the French powertrain manufacturing industry. Our analysis shows that all of the scenarios lead to a relatively steep decline in employment between 2019 and 2030. Scenarios 1 and 2 entail the most pessimistic assumptions and would deliver the most negative outcomes.

On the other hand, we have identified two factors that would contribute to preserving employment beyond 2030: maintaining engine production; and/or relocating upstream part of the value chain. These factors would produce more optimistic results for employment, as shown in scenarios 3 and 4.

Comparative analysis also shows, however, that there is no destined job reduction effect as a result of electrification: ambitious public policy measures can offset, to a certain extent, electrification's negative impact on employment. In our models, the strongest job losses are predicted in those models that assume an absence of a policy response (scenarios 1 and 2), and not those that are based on rapid electrification and/or substantial drops in volume.

Moreover, it worth noting that we have only analysed the car engine sector; new jobs could be created in associated industries that are outside the scope of our data. The following subsection briefly discusses that issue.

Figure 24 **Employment developments according to the different scenarios**



Source: Syndex database.

Recycling of batteries

The recycling and recovery of batteries at the end of their life constitutes a potential source of new jobs that is difficult to assess at present.

The increase in the number of EV batteries in circulation on the market will lead to the development of activities to give them a second life: an EV battery that leaves a vehicle can be reused in stationary applications, as a complement to a sustainable energy source, for example. Car manufacturers and most battery players have identified this opportunity and are communicating on battery reuse projects. This is the case in France with Renault, where one of the building blocks of its 'Re-Factory' project in Flins consists of the disassembling and reconditioning of EV batteries after they have been dismantled from an out-of-use electric vehicle.

When it is not possible to recondition EV batteries, it is necessary to break them up and recycle them. Such processes require a specific treatment that only a few actors can currently provide on the French market. However, the cost of the raw materials used in batteries (mainly cobalt, but also nickel, manganese and lithium), as well as the obligation imposed by the European directive on batteries to achieve a minimum recycling rate of 50 per cent, should foster the development of industrial processing capacities for used batteries.

The environmental impact of battery recycling can be measured at various levels:

- reduction in local pollution at raw material extraction sites: soil and groundwater pollution;
- reduced carbon footprint in the battery production phase;
- traceability of batteries, limiting the risks that they end up abandoned in the natural environment.

The French Strategic Committee for the Mining and Metallurgy Sector estimates that 50 000 tonnes of EV batteries will need to be recycled from 2027 in France, a figure that should increase as electric vehicles become more widespread in the French car fleet. It has not been possible to establish an employment index based on the number of tonnes of batteries to be recycled, as there is no homogeneous and detailed data available to date: this is still a quite new activity that is currently being developed. We estimate that the jobs to be created in a French EV battery recycling industry could amount to between 2000 and 9000 from 2035, provided that this activity is not relocated to countries with lower labour costs or fewer environmental constraints. However, a more profound analysis would be necessary, taking into consideration data from the industrial projects that are bound to develop in the coming years. Further research is needed in that direction.

CO_2 emissions by scenario

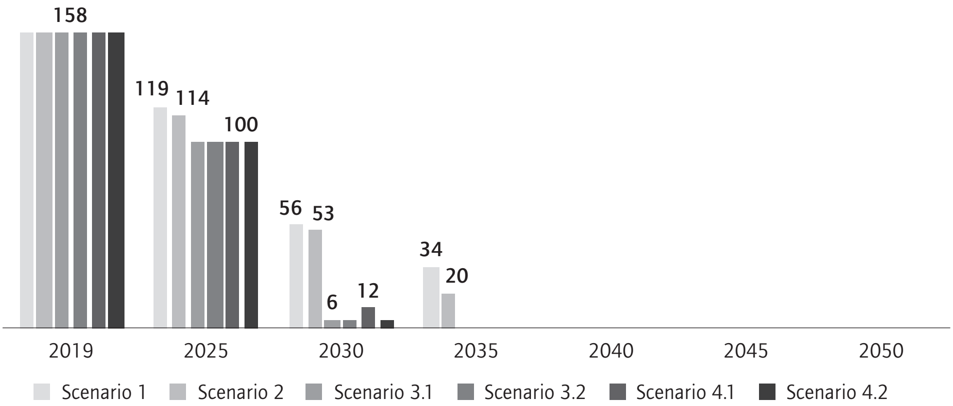
Although the core focus of our study is employment, we have also analysed the CO_2 impact of our models. Rough estimates show that the average CO_2 emission rate of engines assembled in France should significantly drop from 2025: a fall of 25 per cent in terms of CO_2 gr/km in scenario 1 to one of 37 per cent in scenarios 3 and 4. The differences between these two figures can be explained by the choices made in our scenarios concerning the speed of the electrification of production.

With the assumed market exit of thermal combustion engines, CO_2 emissions should fall to close to zero by 2035 (scenarios 3 and 4) or by 2040 (scenarios 1 and 2) at the latest.

Figure 25 shows the number of cumulative grammes of CO_2 emitted on average per engine from French production based on our different assumptions. In estimating the development of CO_2 emissions, we have used data from different sources:

- an average emission rate per vehicle according to the HBEFA (Handbook of Emission Factors for Road Transport) as of Version 4.1 (August 2019);
- for plug-in hybrids, the assumptions used have been adapted from the HBEFA reference;
- differences between diesel, petrol, plug-in hybrid, electric and fuel cells have been taken into account. Light hybrids are included among thermal combustion engines;
- the average rate for each of these technologies changes between 2020 and 2050.

Figure 25 **Average emissions per engine produced in France (gr/km)**



Source: Syndex database.

6. Conclusion

In this chapter, we used our unique database to assess the potential impact of electrification on employment in the French powertrain industry. Our scenarios have shown that we expect a general decline in employment in that branch of the industry. The amount of job loss, however, varies according to the assumptions on which the models are based. Some conclusions can be drawn from the analysis.

First, our scenarios predict a reduction in employment in the range of between 15 000 and 40 000 jobs. It is worth remembering, however, that our data and the analysis is limited to the powertrain. Comparing our findings to the figures presented for the entire French automotive industry in Figure 2 (with total employment of 224 000 in 2019), 40 000 job losses would represent a decrease of 18 per cent in overall employment in the car industry, all other things being equal. For the mildest scenario (3.2), electrification would affect 7 per cent.

Second, we have shown that a 'laissez faire' approach of a continuation of the recent pathways of industrial policies and company strategies delivers the worst possible outcome in terms of employment. We have made the deliberate choice of introducing a voluntarist component into our models and our assessment demonstrates that policy choices do matter. In fact, the scenarios with the weakest negative impact on employment are those that promote ambitious reduction targets, lower volumes and changes in industrial policies, notably in terms of a shift towards locally sourced components. Volume and the requirement for labour do matter, but our data suggest that they are not the most decisive determinants. Policymakers and company leaders have a strategic choice to make if mobility is to become electric and sustainable without destroying many well-paid and often highly skilled jobs in France and in Europe.

As we have discussed above, our study provides detailed information on a clearly defined part of the industry. We have only briefly touched upon, in Section 4.3, some new activities related to electromobility that might drive the creation of new jobs beyond the scope of our database. Studies with a broader focus have, however, looked in more detail at the employment effects of such new activities (the German ELAB studies (e.g. Bauer et al. 2018) are probably the most comprehensive that have been published to date).

To manage the transformation towards electric driving most successfully, it would be of utmost importance to foster significant investment in both research and development, as well as in the training of existing and future employees. Public policy initiatives at local and European level seem indispensable to make sure that employment remains in, or returns to, the customer base (which is, in our case, Europe). Adequate policy tools do seem to be necessary to convince internationally acting players in the field to adapt their sourcing and production strategies accordingly.

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All links were checked on 17.01.2023.

Annex

Table 1 **Scenarios and key assumptions**

	Scenario 1	Scenario 2	Scenario 3.1	Scenario 3.2	Scenario 4.1	Scenario 4.2
	Continued deindustrialisation ('laissez faire')	Economic upturn	Industrial relaunch	Industrial relaunch with local value chains	Industrial relaunch with local value chains and the end of the internal combustion engine by 2035	Industrial relaunch with local value chains and the end of the internal combustion engine by 2030
Market development	Greater openness to imports	One-third of light passenger vehicles are sold in France	50% of products are sold in France	50% of products are sold in France	Production based on the national and regional market	Production based on the national and regional market
Strategic political choices	Continued deindustrialisation	Strengthening of France's position within the EU	Industrial relaunch	Industrial relaunch with local value chains	Industrial relaunch based on local value chains by 2035	Industrial relaunch based on local value chains by 2030
Volumes in 2050 (million engines)	1.35	2.26	3.0	2.5 (by 2030 and stability thereafter)	2.33 (by 2030 and stability thereafter)	2.33 (by 2030 and stability thereafter)
End of internal combustion engines (year)	2040	2040	ICE: 2030 PHEV: 2035	ICE: 2030 PHEV: 2035	2035	2030
Energy mix in newly registered cars	2040: 80% BEV 20% fuel cells	2040: 100% BEV	2035: 100% BEV	2035: 100% BEV	2035: 90% BEV	2030: 80% BEV
Battery production in France (GW)	51.4	113	150	125	94	94
Local supply chains	0%	0%	0%	+30%	+30%	+30%

Table 2 **Average CO2 emissions per engine produced in France (gr/km) by technology**

Year	2020	2030	2040	2050
Diesel	159	149	133	117
Petrol	168	148	133	117
PHEV	84	30	25	25
Mild hybrid	168	148	133	117
BEV	0	0	0	0
Fuel cell	0	0	0	0

Source: Syndex.

Chapter 5
The German path to electromobility and its impacts on automotive production and employment

Martin Krzywdzinski, Grzegorz Lechowski, Jonas Ferdinand and Daniel Schneiß

1. Introduction

The transition from the internal combustion engine to electromobility represents a fundamental challenge for companies and employees in the automotive industry; this technological change being primarily driven by the need to achieve the climate protection targets of the European Union (EU) (Pardi 2021). As part of the Paris Climate Agreement, the EU is committed to reducing greenhouse gas emissions by 40 per cent compared with 1990 levels by 2030; furthermore, in 2020 the European Parliament increased this target to 60 per cent. Accordingly, the EU's CO_2 emission limits for the transport sector have also been tightened: permissible CO_2 emissions from passenger cars fell from 130 to 95g CO_2/km in 2020, meaning that the EU has the strictest emission limits in the world. In addition, the European Commission has proposed reducing emission limits to zero by 2035.

The EU's ambitious climate policy goals are currently exerting strong pressure on the German automotive industry, largely because it has, over a long period, neglected the development of alternative drive technologies, instead focusing on optimising the internal combustion engine (ICE). The failure of this strategy, revealed in the Dieselgate scandal (Mujkic and Klingner 2019), has paved the way for technological change in the industry. Furthermore, in the context of the Covid-19 crisis, the German government decided to provide massive support for sectoral innovation processes and the development of the domestic market for electric cars, providing generous stimulus programmes (Lechowski et al. 2023). With this, German automotive companies have started a radical and fast transition to electromobility.

However, this transition, which is now accelerating, will have fundamental implications for domestic value creation and employment in the industry. By the time of the Covid-19 pandemic in Europe in 2020, the industry in Germany employed more than 800 000 people – a large number compared with other traditional car manufacturing countries in the EU, such as France or Italy. However, the production of electric cars is likely to require significantly fewer workers than the production of cars with internal combustion engines (Bauer et al. 2018). Accordingly, fears of significant employment losses are currently dominating the public debate in Germany (Blöcker 2021). In this context, a number of analyses have been published over the last few years that quantify the potential employment effects of the transition to electromobility in Germany based on different assumptions and scenarios. However, the results of these studies are ambiguous and oscillate between forecasts of massive employment losses and gains

(Bauer et al. 2018; Diez 2017; European Climate Foundation 2017; Kaul et al. 2019; Mönning et al. 2018; Peters et al. 2013; Schade et al. 2014, 2020)[1].

Against this background, our goal in this chapter is to shed light on the employment implications of the ongoing transition to electromobility in the German automotive industry. More specifically, we want to address the following three sets of exploratory research questions:

1. How are the strategies of German automotive companies changing regarding electromobility? What implications may the changing technology and product strategies have for domestic value creation and employment?
2. What are the forecasts regarding the employment implications of the transition to electromobility for the automotive industry in Germany? How should the assumptions and findings of these forecasts be assessed against the background of the current strategies of automotive companies?
3. What role does the Covid-19 crisis play in the transition to electromobility? How can the direct economic impacts of the crisis and crisis-era state interventions in the industry affect the pace and direction of this transformation?

In the case of the German automotive industry, this chapter examines the transition processes in the largest national economy in the EU. The industry has been very successful with a product strategy focusing on the middle, upper and premium market segments and has been able to reconcile a high level of employment in Germany with the extensive use of low-wage locations in central eastern and south-eastern Europe (Jürgens and Krzywdzinski 2009; Krzywdzinski 2014). However, Dieselgate blew up into a dramatic event after which the industry had to reorient its strategies. Here, the Covid-19 crisis created a window of opportunity for restructuring: the massive slump in demand and production led to job cuts at a time when the state was responding with a massive economic stimulus programme to promote and facilitate the transition to electromobility.

In methodological terms, the study is based on an analysis of company reports and press material as well as a systematic comparison of available studies on the employment effects of the transition to electromobility in Germany. The chapter is structured as follows: Section 2 discusses the German automotive industry's production model to date, while Section 3 addresses the hastening reorientation of the strategies of German automotive companies since Dieselgate and the onset of the Covid-19 crisis. Section 4 presents a comparison of the selected studies on the effects of this transition on employment in the industry in Germany. Finally, Section 5 places the described transition dynamics and employment implications in the current context of the Covid-19 crisis, which we call an accelerator of technological change in the industry.

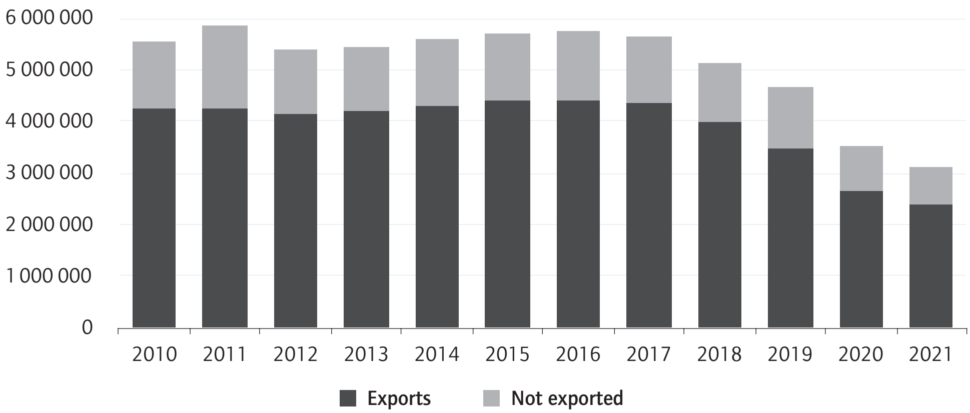
1. We review some of the results of these studies in the annex.

2. The productive model of the German automotive industry

During the first two decades of the twenty-first century, the key characteristic distinguishing the German automotive industry in the EU context has been the country's large domestic production base. Between the early 2000s and 2018, Germany managed to maintain a very high volume of domestic passenger car production: at a level of around five to six million vehicles per year (OICA 2022). In the same period, production numbers have not only been much lower but have also significantly fallen in other traditional European car-producing countries, such as France and Italy (cf. Pardi 2020). In France, for instance, production volume almost halved from around 3.3 million in 2002 to 1.7 million in 2018 (OICA 2022).

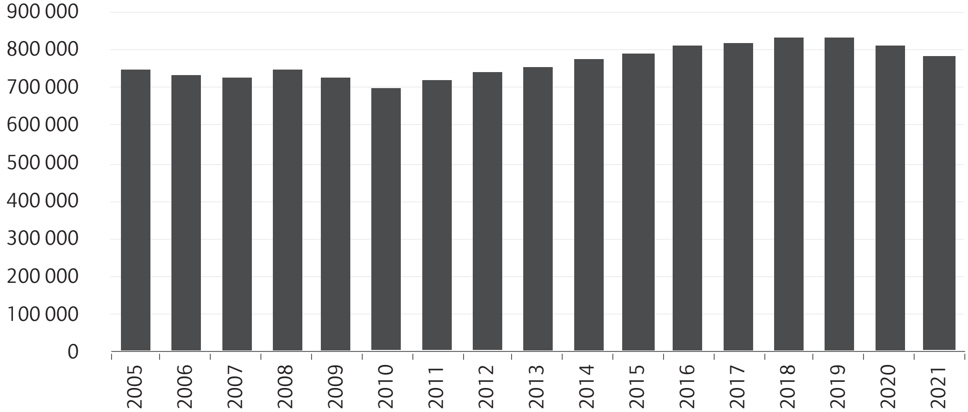
In addition to large output, Germany has also managed to maintain high employment levels in the industry. In the years directly following the global financial crisis of 2007-08, automotive employment in the country only slightly decreased; and, in 2018, after a few years of continuous growth, it achieved an unprecedented level of over 830 000 jobs. However, at the same time, there are clear indications in the statistical data that these positive trends were already reversing. As shown in figures 1 and 2 below, in the years directly preceding the outbreak of the Covid-19 pandemic, both domestic production and employment levels in the German automotive industry started decreasing. During the two years of the Covid-19 pandemic (2020-21), employment dropped by nearly 50 000 jobs, from 830 000 to 786 000.

Figure 1 **Passenger car production in Germany (produced cars), 2010-21**



Source: Statista.

Figure 2 **Employment in the German automotive industry, 2005-21**



Source: Statista.

The peculiar resilience of the domestic automotive production base during the last two decades has been related to a number of factors. At firm level, two of these are particularly important. First, the key German carmakers (OEMs) have successfully managed to position themselves in the lucrative market segments of 'premium' vehicles – and they have accomplished this not only in Europe but also in a number of other key global markets (such as the US and China). The focus on premium markets also helped German automotive OEMs during the Covid-19 pandemic because they concentrated on the particularly profitable SUV and premium car segments, compensating for the loss of production volumes with increased per car revenues. As Sorge and Streeck (2018) point out, this specialisation has been based on certain supportive institutional foundations, including the specific system of innovation (which is based on close cooperation between OEMs, suppliers, equipment manufacturers and research institutes), the vocational education system and cooperative labour relations (cf. Krzywdzinski 2014).

Second, many German automotive firms, while maintaining significant manufacturing operations in their home country, have simultaneously relocated parts of their production activities to various low-wage countries – here focusing especially on production sites in central eastern Europe (Jürgens and Krzywdzinski 2009; Krzywdzinski 2017, 2019; Schwarz-Kocher et al. 2019). This trend has been particularly visible in the automotive supplier sector. At the end of the 2010s, imports from low-wage countries already accounted for about half of the entire value of the automotive components imported to Germany – representing a much higher level than, for instance, the level observed in the French automotive industry (Frigant and Jullien 2018; Frigant and Layan 2009). The extensive usage of low-wage production has also contributed to the price competitiveness of the German automotive industry.

Why then did the relocation to low-wage countries not hollow out the German car industry, as some researchers predicted in the 1990s (Sadler 1999)? Keeping a relevant production base in Germany has been possible because many of the German supplier production plants developed a specific strategy, focusing on so-called 'lead plant' roles

(Krzywdzinski 2019; Schwarz-Kocher et al. 2019). Lead plants specialise in the most innovation-intensive technologies, production activities and products. Their advantage is their ability quickly to introduce new technologies and products. However, as soon as the products achieve higher maturity, the supplier companies relocate their production to low-cost countries, putting permanent reorganisation pressure on the German plants.

3. Changing technology and product strategies in the post-Dieselgate era

Although the established model of automotive production in Germany has proven to be very successful over the past two decades or so, its future has become increasingly uncertain in the context of the ongoing transition to electromobility. One of the key reasons for this is that, for a long time, the existing domestic production base in Germany remained critically dependent on internal combustion engine technology. Both the key German carmakers and suppliers who maintain significant production capacities in their home country have long neglected investment in alternative powertrain technologies and such emerging key value chain segments as electric batteries. Until the outbreak of Dieselgate in late 2015, the overall strategy adopted by the German industry to meet the increasingly stringent EU emission standards was to keep optimising the combustion engine. However, the disclosures that led to the Dieselgate crisis revealed that these alleged ‘improvements’ were, at least in some part, achieved through intended technical deception. As a result of the crisis, German automotive companies suffered immense public image problems and had to pay billions in fines and settlements in some countries. According to company data, VW alone was forced to pay more than 30 billion euros (Lange 2021; Techxplore 2021). In addition, the further tightening of EU emission regulations in the years following Dieselgate and – perhaps especially – the recent introduction of fines for carmakers who do not meet the standards have further reduced the viability of combustion engine-based business models in the industry.

Whereas German automotive companies had long neglected electromobility, they have now shifted to a radical offensive with the aim of transferring the strength of their own products, particularly in the upper and premium market segments, from the internal combustion engine to electromobility. In addition, rapid change had to take place if penalty payments from the tightening of emission limits were to be avoided.

After the crisis of Dieselgate, Covid-19 became another accelerator of change. The collapse in demand and in production in 2020 brought on by the crisis, the latter because of the disruption to global supply chains, prompted a decisive response from German policymakers. After brief deliberations, a major support package for the automotive industry was passed, with purchase incentives for electric vehicles as its centrepiece. This involves purchase premiums of 9000 euros for battery electric vehicles (BEVs) and 4500 euros for plug-in hybrids (PHEVs) over the list price of the vehicles, half being borne by the government and the other half by the companies themselves. In addition to the purchase premiums, the state promised a rapid expansion of the charging infrastructure. Added to this was a billion-euro package to support innovation in the fields of digitalisation and Industry 4.0 (Lechowski et al. 2023).

Although there were calls to extend the purchase premiums to fuel-efficient internal combustion engine vehicles (ICEVs) as well, carmakers backed the demand for premiums for pure electromobility. It was clear that any postponement of the change would be expensive because of the threat of penalties at EU level. The strategy proved successful: the share of BEVs in new registrations in Germany rose from under 1 per cent in 2018 to nearly 18 per cent in 2022; the share of PHEVs rose from just under 4 per cent to over 31 per cent.

In the remaining part of this section, we take an explorative look at the new technological and product strategies of the German automotive companies that have been developed by firms in the post Dieselgate context. In so doing, we highlight the possible implications of these emerging strategies for the domestic production base and employment in Germany.

3.1 Electrification strategies of key German OEMs

Focusing first on the case of German automotive OEMs, although all three firms have increasingly focused their product and technology strategies on electrified powertrain concepts, some significant differences between these strategies are nevertheless visible.

The largest of the three, Volkswagen Group, is pursuing a particularly ambitious strategy. The company recently set a target of a market share of electric vehicles (EV) of around 50 per cent of total sales by 2030 (Volkswagen 2021). In addition, some of the brands within VW Group will pursue even more ambitious goals. One example is the VW brand, which is aiming for a 70 per cent share of EV sales by 2030. Even more radical is the strategy of the Audi brand, which plans to launch only EVs from 2026. Audi's strategy implies that the production of ICEVs in Europe will end around 2032-33 – although it may continue after this date in various low- or middle-income markets, such as South America.

VW Group has already introduced a dedicated EV platform, Modularer E-Antriebs-Baukasten (Modular Electric Drive Platform; MEB), which is used to produce different EV models across different brands. The MEB will also be offered to other OEMs, and Ford of Europe has already announced its plans to use the MEB platform for EV production at its Köln plant. This strategy is meant to produce scale effects which could make EVs more affordable.

In terms of investment in new technology development and productive capacities, VW Group wants to build significant in-house capabilities along the entire battery supply chain, from the management of raw materials extraction to battery recycling (Volkswagen 2021). To secure the supply of battery cells for its own production of EVs, the company plans to build six battery factories with a total capacity of 240 gigawatt hours (GWh) per year in different European locations: in Germany (together with the

Chinese partner Gotion); in Sweden (with Northvolt); and in Spain. By 2030, these plants are expected to supply 80 per cent of all battery cells for the European production of VW Group. In cooperation with these partners, VW Group also plans to develop its own battery cell. In addition, the company is making significant investments in the construction of its own charging infrastructures in Europe, China and North America.

The second German automotive OEM by size, Daimler, has also recently intensified its electrification efforts and has begun pursuing an 'electric only' strategy (Daimler 2021). On the one hand, the company is re-emphasising its willingness to focus on the highest value added 'premium' market segments, where profit margins are highest. On the other hand, by 2025, half of its sales should already be coming from either full electric or hybrid vehicles. Moreover, in 2021, the company announced its decision to abandon any further new development of hybrid vehicles (Handelsblatt 2021); it sees these as too expensive because they have to combine two powertrain technologies.

From a product-architectural point of view, the company introduced its first full electric platform in 2021 and, by 2025, all of its new product developments should be based on dedicated fully electric platforms. Regarding the geographical footprint of its production activities, Daimler currently produces EVs at seven facilities (Elektroauto-News 2020): three domestic plants (Sindelfingen, Rastatt and Bremen); and four locations outside Germany (Kecskemét in Hungary, Vitoria in Spain, Beijing in China and Tuscaloosa in the US).

In Germany, as part of ongoing reskilling programmes, around 20 000 Daimler employees received training in the field of electromobility in 2020 (Daimler 2021). Furthermore, the company is also investing in the development of new capabilities. To strengthen its own product development competencies, Daimler acquired the British company YASA, which specialises in electric motors with the aim of obtaining access to 'technology in the field of axial flux motors and expertise for the development of ultra-high performance axial flux motors' (Daimler 2021). Mercedes-Benz also plans to develop and produce battery cells and modules in Europe with the help of new partners. In the development of battery cells, Daimler is working with SilaNano to achieve an 'increase in energy density through a significant increase in the proportion of silicon at the anode', which would enable a measurable increase in range and a shorter charging time.

The company is also expanding its own production capacities. First, in 2021, Daimler announced its plans to join the government-supported battery cell manufacturing project Automotive Cells Company (initiated by Stellantis and the French energy company TotalEnergies/Saft). This joint venture should achieve a production capacity of 200 GWh by 2030, including a new production facility in Kaiserslautern, Germany (with a production capacity of c. 20-30 GWh). Daimler's other investments in the battery supply chain include its own battery pack production (developed together with the German machine tools company GROB) and a battery recycling facility to be located in Germany. Beyond battery manufacture, the company also plans to internalise the development and production of electric motors (Daimler 2021), increasing its efforts to build its own charging infrastructures.

Finally, the third key German automotive OEM, BMW, made an early entry into the emerging EV market by establishing a dedicated sub-brand for electric cars (BMW i) in 2011, introducing its first purpose-designed fully electric model (the BMW i3) in 2013. Because of its technologically groundbreaking characteristics – such as the modularised chassis architecture combining a lightweight carbon fibre body for the passenger compartment with an aluminium module for the powertrain area (Alochet and Midler 2019) – the BMW i3 has been recognised as an example of an exceptionally 'transformative' product innovation style in the industry (Sovacool et al. 2019). However, despite this early lead, BMW's overall product and technology strategy during the last decade has not been technologically more progressive than the strategies followed by VW and Daimler.

Regarding its product portfolio, BMW's much-praised early electric models were discontinued in 2020 and 2022 because of their rather disappointing market performance in the face of growing competition. The company did introduce two other fully electric models in 2021 (iX and i4) and is planning to launch an entire new generation of purpose-designed fully electric models based on a new vehicle platform around 2025. However, with the sole exception of the iX, all other electric models currently produced by BMW rely on multipurpose platforms developed primarily for ICEV or hybrid powertrains. In addition, although the company plans to reach the threshold of a 50 per cent share of fully electric vehicles in its overall production by 2030 (Watzke 2021), management has recently rejected the idea of abandoning the development of new ICEVs altogether. Instead, the company intends to follow a more technologically open strategy – at least, during the coming 10 years or so.

This perhaps more hesitant stance toward electromobility has also been reflected in BMW's decisions regarding the development of new production capabilities. For a long time, the company hesitated to invest in its own full-scale production of battery cells. Instead, it has relied on external battery cell suppliers, conducting relevant research and small-scale manufacturing activities in a few German plants simply to specify component requirements. Only in 2021 did BMW launch series production of battery modules and packs at its Leipzig and Regensburg plants (Werwitzke 2020).

3.2 Transition processes in the German automotive supplier industry

Although some significant differences exist between the key German OEMs regarding their electrification strategies, the situation is even more complex in the supplier industry. On the one hand, a recent survey conducted by Deloitte and Verband der Automobilindustrie (German Association of the Automotive Industry; VDA) (Deloitte and VDA 2021) suggests that a vast majority of automotive suppliers agree that electromobility will become the dominant powertrain technology in the passenger car industry. In addition, more than 80 per cent of the surveyed companies have already undertaken some kind of measures in response to ongoing technological change. However, at the same time, the overall pace of restructuring is still rather moderate. Based on VDA data, although around 30 per cent of total R&D expenditures among the surveyed suppliers is already spent on products in the field of electromobility, only 15 per cent of firms' turnover is generated by electric drive components. The VDA study comes to the conclusion that the dominant strategy of German automotive suppliers is not a strategy of a rapid 'exit' from ICE technologies but rather a double-tracked approach that is focused, first, on exploiting the existing product market and, simultaneously, on investing some resources in the development of new technologies.

To gain a better understanding of the strategic dilemmas with which the German supplier sector is currently being confronted, we take a closer look at the transition processes taking place in three selected large and well-known companies, all of them representing supplier firms with significant but varying levels of dependency on the ICE technological regime.

The first company, Bosch – the largest automotive supplier worldwide – will be strongly affected by the transition to electromobility because of the firm's dominant position in the fuel injection systems market. Recently, the company has started investing in various new technological capabilities which will be of critical importance in the production of electrified and IT-intensive 'next generation' vehicles, such as autonomous driving systems or innovative semiconductor technologies. Bosch wants to become a supplier of all the critical components for electromobility including electric engines, batteries and electronic components (Bosch 2018). Management expects that the internal combustion engine will still represent a relevant market opportunity (e.g. in the segments of hybrid or commercial vehicles) (Höltschi 2020), but the company has started implementing significant employment reduction measures related to its technological restructuring programme. In 2020 alone, 6800 jobs were to be cut worldwide (including 2000 in Germany).

Another important German supplier firm, ZF Friedrichshafen, has historically maintained a powerful market focus on the production of transmission systems for ICEVs. However, in the last few years, the company has made efforts to shift its business model to more future-proof component technologies, such as hardware and software components for automated driving solutions or drivetrain components for electric cars. In 2020, ZF announced its decision to withdraw completely from the combustion engine component market (Reichel 2020). The company is developing its own concept vehicle called EVPlus to demonstrate the performance of its own technologies in terms of miniaturisation and weight reduction, as well as transmission performance. With its products, ZF aims not only to reach established OEMs but also to offer new entrants to the market a complete platform for developing their own EVs. As part of these conversions, ZF has established a new division for electromobility. However, the company has also introduced significant employment restructuring measures, including 6500 job cuts in 2020 alone with 15 000 more expected in the coming years (Borkert 2021).

Finally, our third selected case, Mahle – Germany's sixth largest supplier, with strong capabilities in the production of conventional combustion engine components such as pistons, cylinders and valve controls – represents the type of company that may be most severely affected by the ongoing electrification processes. Mahle is currently attempting to diversify its technology scope toward various low-emission powertrain technologies, for instance by launching R&D projects focused on innovative combustion engine concepts (including hydrogen engines), fuel cell technologies and electric motors (Rasch 2021). In 2010, the company had already taken over Behr, thus acquiring technologies in the field of air conditioning and thermal management. The company hopes to use these competences to develop air conditioning systems designed for EVs. Starting in 2014, the company began developing its own electric motors and presented its first product in 2021 (Rasch 2021). However, as part of its continuing technological restructuring programme, Mahle has already implemented significant austerity measures and employment reductions. For instance, in 2020 it announced 7600 job cuts worldwide, including 2000 in German locations.

3.3 Conclusion

Overall, since the Covid-19 crisis, the German automotive industry has begun a radical shift toward electromobility. It seems that this shift has been able to compensate for the slow and late start of German companies in the BEV market. Given the plans and announcements of the German manufacturers, it seems relatively realistic that BEVs could account for a 50 per cent share of automotive production in Germany by 2030, here under the assumption that the expansion of the charging infrastructure will allow for such growth.

In addition, automotive companies and suppliers are investing in building up the skills required for the production of electric motors and batteries and are developing production sites in Germany and Europe. Thus, it is also not unrealistic that the previous trend of almost completely importing batteries from Asia will be broken and that significant steps in the production of these technologies will be located in Europe and Germany.

Finally, German carmakers and suppliers are investing in new technologies that can deliver decisive competitive advantages after the end of the internal combustion engine: these include technologies in the field of electromobility but also the connected car, autonomous driving and others. However, these investments go hand-in-hand with equally decisive restructuring steps regarding existing production and employment.

4. Employment implications of the turn to electromobility in Germany: a meta-analysis

The explorative insights into the changing technology and product strategies of the German automotive industry that have been discussed in the previous section indicate that, although the ongoing transition to electromobility will affect different firms in different ways, the overall risks for employment in automotive production are indeed significant. In this section, we complement this picture with an in-depth review of existing forecasts assessing the impact of the transition in the German industry on domestic employment. Although an extensive body of such studies exists, the analyses follow distinctive methodologies and assumptions, hence making a direct comparative interpretation of their results difficult.

To narrow down the scope of our analysis to those forecasts that rely on relatively up-to-date assumptions regarding the characteristics and perspectives of EV technologies and markets, our review focuses on studies published within the last decade (i.e. since 2012). Furthermore, we only review country-level studies, thus excluding the numerous forecasts developed for individual federal states in Germany (Malorny and Linder 2012; Sujata et al. 2020).

Within this narrowed-down field of search, we could identify two main types of employment impact analyses in the German debate. First, there are analyses that take a relatively narrow perspective and discuss the direct employment effects of the switch from the combustion engine to the electric drive. More specifically, these studies usually depart from quite detailed descriptions of technological change at the level of automotive products (both individual components and entire vehicles) and, building on this, assess instead the related employment implications in terms of the changing demand for different kinds of production activities and jobs across the automotive value chain.

The second type of study adopts a broader economy-wide perspective. Most such studies use macroeconomic input-output models to assess the employment shifts directly related to the changing character of production activities in the traditional automotive manufacturing industry as well as the employment effects related to the shifts in demand for various kinds of jobs in the national economy in the context of the electrification of the car. This includes, for instance, the emerging demand for new kinds of service work or the labour market effects of the infrastructural investments necessary for the transition.

In the following, we present the results of our review based on this heuristic distinction between these two types of study. Table 1 gives a comparative overview of the selected studies. We provide a summary description of the selected studies and scenarios in the annex. Although some of these examined analyses formulate multiple scenarios, in each case we restrict our discussion to one scenario by selecting that which is closest to the prediction of BEVs having a 50 per cent share of German automotive production by 2030. Moreover, in cases where the examined studies present various possible scenarios regarding the localisation of battery production, we focus on the one which assumes that relevant production activities will indeed be located in Germany. Not all studies, however, include such a scenario.

The two studies that focus on the direct employment effects of the transition from the internal combustion engine to BEV (Bauer et al. 2018; Diez 2017) conclude that there will be employment losses in the automotive industry. These losses amount to up to 80 000 jobs if battery production does not take place in Germany but drop to 16 000 if it proves possible to locate a relevant part of the battery production value chain in Germany.

In the studies based on macroeconomic input-output models, a large number of assumptions come into play, making direct comparisons particularly difficult. If we disregard the respective specifics of the models and focus on those factors related to the transition, two factors seem to be particularly relevant.

Table 1 **Employment effects of electromobility in the German automotive industry**

Reviewed study (and scenario)	Analytical perspective	Year in which BEVs reach 50% share of production *	Expected production volume (number of cars)	Expected net employment increase/decrease in the automotive industry
Bauer et al. (2018) (ELAB); scenario 2	Micro-analysis of direct employment effects on automotive production	2030 (40% BEV; 20% PHEV)	c. 5.75 million (2030)	2030: loss of 90 000 jobs out of 810 000 in 2016 (battery production mainly not in Germany)
Diez (2017); scenario 'evolutionary diffusion'	Micro-analysis of direct employment effects on automotive production	2030 (50% BEV; 20% PHEV)	c. 5.75 million (2030)	2030: loss of 16 000 jobs out of 613 000 in passenger car production in 2015 (with battery production mainly in Germany); or loss of 55 000 jobs (with battery production mainly not in Germany)
Peters et al. (2013)	Macroeconomic input-output model	-	c. 5.5 million (2030)	2030: gain of 17 600 jobs on 700 000 in 2010 (battery production mainly in Germany)
Schade et al. (2014); scenario 'technological break (pessimistic)'	Macroeconomic input-output model	2030 (50% BEV + PHEV)	c. 7.3 million (2030)	2030: gain of 192 000 jobs on 700 000 in 2010 (battery production partially in Germany)
European Climate Foundation (2017); TECH scenario	Macroeconomic input-output model	2040 (49% BEV; 18% PHEV)	-	2040: loss of 5000 jobs from 2016 level [but considerable increase in employment in overall economy]
Mönning et al. (2018)	Macroeconomic input-output model	- (2035: 23% BEV)	c. 5.0 million (2030)	2030: loss of 50 000 jobs out of 830 000 in 2018 (battery production mainly not in Germany)
Kaul et al. (2019); scenario 'increasing electrification'	Macroeconomic input-output model	2035 (48% BEV)	c. 6.5 million (2030)	2035: loss of 130 000 jobs out of 920 000 in 2017 (battery production mainly not in Germany)
Schade et al. (2020); scenario 'e-road'	Macroeconomic input-output model	2025-30 (2030: 71% BEV; PHEV 21%)	c. 5.8 million (2035)	2035: gain of 7000 jobs on 975 000 in 2018 (battery production in Germany); [considerable employment increase in overall economy]

* Not all studies provide this information; the expected share of BEVs and PHEVs are contained in brackets.
Source: Authors.

First, employment outcomes again depend on whether it is assumed that battery production will take place in Germany. Studies that assume that batteries are largely imported conclude that employment losses in the German automotive industry range from 50 000 jobs (Mönning et al. 2018) to 130 000 (Kaul et al. 2019); input-output studies that assume the location of a relevant part of battery production in Germany indicate small employment increases in the automotive industry (Peters et al. 2013; Schade et al. 2020).

Second, it is crucial to note which assumptions are made regarding the development of demand and, thus, of the production volume and value added in Germany. Schade et al. (2014), for example, forecast particularly high employment growth from the transition but, in their model, this is accompanied by very optimistic assumptions regarding the development of production volumes. Against the backdrop of the 2020 slump in demand and production, however, the question arises as to whether the sales volumes achieved before the Covid-19 crisis will again be reached in the future. Schade et al. (2020) are more cautious about production volumes but still assume that production can indeed reach pre Covid-19 levels. However, their result of positive employment effects from the transition is based on the assumption that the German industry's upgrading and premium strategy (e.g. through new value creation in the area of driver assistance systems and electronics) can be continued and is accompanied by further export successes.

Therefore, the decisive factors for the future development of employment in the automotive industry are, on the one hand, the extent to which production volumes can reach the levels prior to Covid-19, where value creation can be built up in the area of battery production and electric motors; and, on the other, the extent to which the technologies surrounding the connected car generate new value creation.

It should also be noted that some of the studies come to the conclusion of very high positive effects of electromobility on employment and value creation in the overall economy, even if employment in the industry does not benefit from this (European Climate Foundation 2017; Peters et al. 2013; Schade et al. 2014, 2020). It should be emphasised, however, that these macroeconomic effects are generated to a considerable extent from assumptions of large public and private investment programmes in the expansion of energy grids, the charging infrastructure and (e.g. Schade et al. 2020) non-automotive transport infrastructure (railways), which will accordingly manifest primarily in the construction, mechanical engineering and energy sectors.

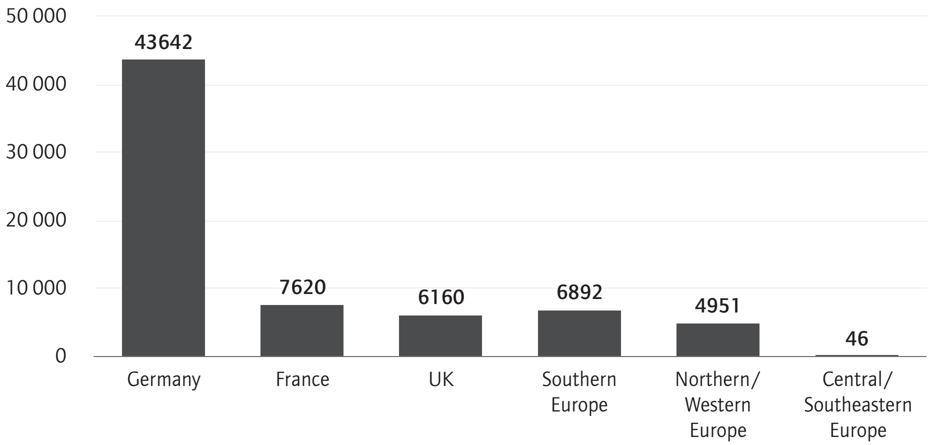
5. The Covid-19 crisis as an accelerator of change

Regardless of whether the existing forecasts of the impact of electromobility on employment in the automotive industry conclude that the employment effects will be negative or positive, they all assume that these will occur in a period up to around 2030-40. Although in the particularly pessimistic scenarios annual employment losses are higher than natural turnover (caused, for example, by retirements) (Falck et al. 2021), this is nevertheless a period during which such change can certainly be managed by companies, employees and society.

However, the situation changed with the Covid-19 crisis. As Figure 1 showed, the crisis was accompanied by one of the largest slumps in the history of production of the German automotive industry. Shortages of microchips and semiconductors, because of disrupted supply chains, contributed to this (Roland Berger 2021). The result was that companies intensified their investments in electromobility exploiting, at the same time, the window of opportunity for employment restructuring that had been opened by the crisis.

As shown in Figure 2, employment in the German automotive industry reached its maximum in 2018 and 2019 at around 833 000 jobs. During the two years of the Covid-19 crisis, nearly 50 000 jobs were lost. However, companies have announced even more extensive restructuring. Figure 3 shows the employment reductions announced by companies in different European countries and regions over the course of the crisis. What is projected here are the net losses; that is, the announced level of employment reduction minus the announced level of job creation (e.g. by the new Tesla plant in Germany).

Figure 3 **Announced net job reduction in the European automotive industry (press reports 1 March 2020 – 1 November 2021)**



Source: Authors, based on the European Restructuring Monitor.

The biggest job cuts in absolute terms have been announced in Germany: over 40 000 jobs are in danger. Measured by the size of their automotive industries, France and the UK have also been significantly affected. Hardly any net job losses are expected for central and south-eastern Europe, the intra-European low-wage region that has been attracting particularly large numbers of production relocations from western Europe.

It is reasonable to interpret that companies are using the Covid-19 crisis to restructure employment more comprehensively, a period in which they are also making the necessary adjustments to the transition from the internal combustion engine to electromobility. The acceleration of these plans amidst a shortening of the adjustment period represents a challenge for employees, trade unions and society as a whole.

As part of its Covid-19 stimulus package, the German government created the Zukunftsfonds (Automotive Industry Future Fund) to support the transition between 2021 and 2025 (Fuchs and Sack 2022; Lechowski et al. 2021). The funds' resources are to be used to support (a) regional collaborations to adapt companies and employees to the transition, with a focus on small and medium-sized enterprises; (b) innovation projects by companies in the areas of digitalisation and manufacturing technology, but also battery cell and electric motor production; and (c) further training concepts for employees. Tenders for the funds' resources were launched in 2021 but analyses of their impact are not yet available.

For IG Metall, the trade union representing workers in the automotive industry, the transition to electromobility represents a challenge. First, IG Metall must represent the interests of employees in job security. Secondly, it must also represent the interests of its members as users of mobility but also as citizens with an interest in and responsibility for a healthy environment. This results in considerable tensions, as Strötzel and Brunkhorst (2019) describe.

These tensions resulted from the trade union having long called for an ambitious climate policy and then for a realistic setting of automobile emission standards that would not overtax the innovative capacity of companies while allowing for the further development of ICE technologies (IG Metall 2015). The background was a considerable difference of opinion within the union since the works councils of automotive suppliers specialising in combustion engine components opposed a clear positioning of the trade union in favour of electromobility. In its paper 'Fit for 55' (IG Metall 2021), however, the union changed its position. It now clearly supports the rapid expansion of electromobility but calls for a number of measures to facilitate the transition: supporting the demand for electric vehicles; expanding the charging infrastructure and renewable energies; locating battery production and raw material supply in Germany or Europe; and securing employment, for example through regional reskilling programmes and a conversion of the current Kurzarbeitergeld (short-time working allowance; KuG) to a Transformation-KuG (short-time transformation allowance) (Strötzel and Brunkhorst 2019).

IG Metall is active at various levels in pursuit of these goals. At national level, the union is involved in the Nationale Plattform Zukunft der Mobilität (National Platform Future of Mobility; NPM) in which it works with the government, companies, environmental associations and experts. Here, the union is pushing for the coordination of industrial, infrastructural and labour policies. One of the union's additional initiatives is the 'Best Owner Group' an investor fund which seeks to secure jobs threatened by the phasing-out of combustion technology.

At company (and also plant) level, the union is trying to secure employment through collective bargaining and reaching pacts with management. Here, OEMs currently find themselves in two worlds: existing electromobility plants have full order books and are associated with long delivery times; the production lines for ICEVs, on the other hand, are severely underutilised, a state which is expected to last for a long time.

Under these conditions, German automotive companies have turned to a bargaining pattern used in the past, one in which they offer employment guarantees and new investment in exchange for concessions on the labour side (Greer 2008; Kädtler and Sperling 2002; Krzywdzinski 2014; Zagelmeyer 2013). Given the pressure on employment, these pacts are, however, 'expensive' for labour. An important subject of such negotiations is the increase in in-house production for e-components to secure new jobs (Strötzel and Brunkhorst 2019).[2]

BMW has announced that it will cut 6000 of its 128 000 jobs worldwide (90 000 of which are in Germany). For the German BMW plants, however, there is an employment guarantee until 2026 negotiated with the works councils which means that there will be no compulsory dismissals. In addition, agreements have been negotiated at individual plants. The Munich plant will be completely converted to electric cars while that at Leipzig will be expanded into a competence centre for battery cell production. At Dingolfing, management has promised a new production line for electric motors. In return, employees will forgo the payment of some wage supplements in exchange for eight additional days leave. In white collar areas, 40-hour contracts will be reduced to 38 hours. BMW is also offering termination agreements on a voluntary basis which have been accepted by 1300 employees (as of February 2022).

Daimler has announced a reduction of 10 000-15 000 of its 300 000 jobs worldwide. Several thousand of these are to be eliminated in Germany, with ICE production in particular to be relocated to Daimler's partner Geely, whose production sites are in China. However, as part of the company's split into Mercedes-Benz and Daimler Trucks, an employment guarantee was negotiated until 2029 in which redundancies are ruled out. The company has also pledged to invest 35 billion euros in German plants and it was agreed that the issues of sourcing components in-house or externally (i.e. decisions on vertical integration) would be negotiated with the works councils – an important extension of the influence of the labour side.

In view of the difficult market situation, the company's 2020 collective agreement was adjusted. First, working hours were reduced by 5.71 per cent (two hours in the case of a 35-hour week) to save labour costs. Second, the employees waived the profit-sharing scheme. In addition, as with BMW, certain wage supplements will not be paid but converted into eight additional days leave. In return, the company has promised to expand the Untertürkheim engine plant into a centre of excellence for electric drives while the engine plant in Berlin-Marienfelde, despite losing employment, will gain the production of electric motors. A digital factory competence centre will also be established in Berlin-Marienfelde to secure the future of the plant.

VW Group had already launched a major cost-cutting programme in 2016 in response to Dieselgate. The plan had been to cut 30 000 jobs by 2025, including 23 000 jobs in Germany although, in the negotiation of the Zukunftspakt (Pact for the Future) with the company works council, this figure was reduced to a net 14 000 jobs by 2020: 23 000 jobs would be cut using severance programmes or partial retirement while, at the same

2. The following overview is based on research by Antje Blöcker (Blöcker 2022).

time, 9000 jobs would be created in future technologies. The agreement also included detailed commitments for new products for German plants: the Wolfsburg plant was promised a new generation of EVs, including the Trinity project – a completely new EV plant; the Kassel plant was promised lead plant role in electric drive transmissions; for the engine plant in Salzgitter, there was the promise of the establishment of battery cell development and series production, along with the development and production of fuel cells (together with Audi); for the components plant in Braunschweig, an e-mobility competence centre and responsibility for battery systems were promised; for the Zwickau plant, there was the promise of the conversion to EV production; and, for the Hanover plant, there will be component production for EVs.

Overall, the employment pacts illustrate the enormous pressure on employment in the German automotive industry: thousands of jobs are at risk. At the same time, these pacts do show how companies and works councils are using tried-and-tested concession bargaining to try to secure the future of the sites and put them on a new technological path.

6. Conclusion

Our goal in this chapter was to shed light on the implications of the ongoing transition from combustion engines to electromobility for value creation and employment in the German automotive industry. The starting point of our analysis was a reflection about the distinctive characteristics of the 'German model' of automotive production in the EU context. Since the beginning of the 1990s, Germany has managed to maintain much higher volumes of domestic production and much higher employment levels in the automotive industry compared with other traditional European car-producing countries, such as France and Italy. This development has been based on a combination of several factors: on top of favourable regulation (Pardi 2021), it is the specialisation in the upper and premium market segments, combined with the considerable globalisation of production networks, that has allowed these to gain a strong presence in markets like China and South America and to benefit from low-wage component imports to improve price competitiveness (Krzywdzinski 2014). However, the viability of the German automotive production model has become increasingly uncertain in the context of ongoing technological change. Our analysis provides exploratory insights into how companies have managed this transition.

Although for a long time German carmakers relied on their specific competitive advantages linked to their technological strength in the field of internal combustion engine technologies, crisis has led to a rapid reorientation of the industry. Carmakers are now focusing on a rapid transition to EVs and are trying to gain competitive advantages in this area by developing their own product development competencies and engaging in new alliances. This turnaround by carmakers is also leading suppliers to reorient themselves and develop new products and business models geared toward electromobility. Given that German companies were hesitant over a long period about investing in electromobility, this turnaround has been astonishingly fast and spurred by crises: Dieselgate shook the industry's faith in diesel technology and led it to withdraw support from it; while the Covid-19 crisis created a window of opportunity, first because companies could now legitimise major restructuring plans by citing it and second because of the German government's massive EV subsidy programme.

It is clear that this transition will cost thousands of jobs, even if the exact employment consequences are difficult to estimate. We compared a number of studies, with all the difficulties related to the use of different methodologies and assumptions. It becomes evident that massive negative employment effects in the automotive industry can only be avoided:

– if at least a relevant part of battery production (and the electric powertrain) will be located in Germany
– the added value per vehicle produced in Germany increases significantly, in continuity with the upmarket and premium strategy of German manufacturers
– production volumes return to their levels prior to Covid-19.

At least in the short term, scepticism is warranted as to whether these conditions can be met. Since 2020, many automotive companies have begun to reduce employment significantly. Nearly 50 000 jobs had already been lost in the German industry by 2021, while severe cuts have also been announced for the following years. In our estimation, companies have at least partially started to realise the structural effects of the transition with this reduction in employment.

In the long term, however, the situation is less clear. The massive investments made by companies could put the growth model of the automotive industry in Germany back on its traditional path. Several employment pacts in the industry – whose particular goal is to buy time – oblige companies to invest in new technologies in their German plants. These company-level efforts are supported by the policy measures launched by the German government in consultation with companies and trade unions. These include not only purchase subsidies for EVs and substantial innovation assistance for companies, but also regional funds for small companies and for further training for employees. All of this represents a classic response in terms of corporatist concertation in the German automotive industry (Fuchs and Sack 2022) – even if labour is obviously in a weak position given the pressure on employment (Hopp et al. 2022; Strötzel and Brunkhorst 2019).

These employment pacts continue the tradition of negotiated change in the industry. Works councils have accepted a reduction in employment as long as it does not mean layoffs but is, instead, achieved through natural labour turnover, severance programmes and early retirement. In view of the difficult situation of companies, works councils and IG Metall have also had to accept cuts in pay, with employees gaining in return additional days leave or shorter working hours. In addition, carmakers have pledged to invest in the production of EVs and components in Germany. Whether enough time has been bought for the transition remains to be seen.

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Annex

Overview of studies on the employment effects of the transition to electromobility in the German automotive industry

Micro-analyses of direct employment effects

– **'Effects of vehicle electrification on employment' (*Wirkungen der Fahrzeugelektrifizierung auf die Beschäftigung*) (Bauer et al. 2018)**

One of the most important studies is 'Effects of vehicle electrification on employment' (the so-called 'ELAB 2.0' study) conducted by the Fraunhofer Institute for Industrial Engineering (IAO), which is an update and expansion of the predecessor study, ELAB 1.0, conducted in 2012 (Spath et al. 2012). The ELAB study examines the direct changes in development and production processes at micro level that occur when switching from combustion engines to electric motor technology.

One of the central assumptions of the ELAB 2.0 study is that battery cell production does not take place in Europe. Accordingly, the value added in the area of batteries includes the assembly of cells into cell modules, as well as the production of casings and additional elements such as sensors, battery management systems and others. Regarding electric motors and their power control modules, production in Germany is assumed.

The starting point for the scenarios developed by the study are the shares of powertrains in 2016; that is, 49 per cent ICEV petrol, 48 per cent ICEV diesel, 2 per cent PHEV and 1 per cent BEV. Potential shifts between vehicle segments, changes in import/export structure and other factors are not considered. However, an important assumption is that, with respect to ICEV, the share of petrol models increases to 75 per cent while that of diesel falls to 25 per cent. The share of mild hybrid electric vehicles (MHEVs) increases to 75 per cent of ICEV petrol and 50 per cent of ICEV diesel.

ELAB 2.0 distinguishes between three scenarios. In the first, BEVs rise to 25 per cent of production by 2030 and PHEVs to 15 per cent. In the second, BEVs rise to 40 per cent of production by 2030 and PHEVs to 20 per cent. The assumption here is that the increase will also be accompanied by the establishment of a corresponding charging infrastructure. If the number of powertrains produced remains constant, these changes will result in an 18 per cent decrease in the number of people needed for manufacturing by 2030 (or 40 per cent if productivity increases are taken into account). In the third scenario, the share of BEVs is expected to increase dramatically to 80 per cent of production in 2030, with the share of PHEVs remaining at 10 per cent. Assuming a constant production volume, this leads to a 35 per cent reduction in the required workforce (or 53 per cent if productivity increases are taken into account).

ELAB 2.0's calculations assume that approximately 35 000 employees were directly involved in the production of one million powertrains in the reference year of 2016. Since 5.75 million vehicles were produced in 2016, ELAB 2.0 assumes that approximately 200 000 employees worked in the production of powertrains (and associated components). Against this backdrop, scenario 2 results in the loss of 36 000 jobs (excluding productivity gains) or 90 000 (with productivity gains); while scenario 3 implies a loss of 70 000 and 125 000 jobs respectively.

– **'The impact of digitalisation and electrification on the development of employment in the German automotive industry'** (Der Einfluss der Digitalisierung und Elektrifizierung auf die Beschäftigungsentwicklung in der deutschen Automobilindustrie) (Diez 2017)

This study calculates the employment consequences of electromobility by calculating the change in value added per vehicle in the transition from ICEV to BEV and extrapolating this based on specific assumptions. Like the ELAB 2.0 study, it belongs to what we call micro-level scenarios. The starting point of the study is 2016, at which time employment in the German automotive industry was around 800 000 (although the study focuses on employment in passenger car production only, which the author puts at 613 000 in 2016).

The first central assumption of the study is that, by 2030, the market position of German carmakers – and, thus, the production level in Germany – will remain largely unchanged at around 5.75 million vehicles. Although a continuation of the relocation of production to low-wage countries is to be expected, this will be compensated for by the expected growth of the automotive market. Regarding the change in value added when switching from ICEVs to BEVs, the study is based on the results of the ELAB 1.0 study (Spath et al. 2012) which concluded that the transition to electromobility will lead to employment losses if the change from ICEV to electric motors is considered in isolation. If the production of the battery pack is included, however, the value added per vehicle increases. Therefore, it is of decisive importance whether battery packs are produced in Germany or abroad.

The study develops two basic scenarios. In the first ('evolutionary diffusion'), the share of BEVs in German automobile production increases to 50 per cent of vehicles by 2030 (plus 20 per cent PHEV). In the second scenario ('accelerated diffusion'), the share of BEVs increases to 70 per cent by 2030 (plus 20 per cent PHEV). In both scenarios, one variant with and one without battery production in Germany are calculated.

In the 'evolutionary diffusion' scenario, there is a loss of 16 000 jobs by 2030 if battery production takes place in Germany; if batteries are imported, the same scenario results in an employment loss of 55 000 jobs in the automotive industry by the same year. In the 'accelerated diffusion' scenario, the employment loss by 2030 is 61 000 jobs (where battery production is located in Germany) or 110 000 jobs (where battery production takes place abroad).

Macroeconomic input-output models

– 'Low-carbon cars in Germany' (European Climate Foundation 2017)

The starting point for this study is the calculation of the expected demand for different vehicles based on assumptions about the development of the prices of different technologies and forms of propulsion, as well as regulatory CO_2 emission limits. The expected demand for different types of vehicle is fed into a macroeconomic model to calculate the impact on value added, employment and other factors.

The study develops a number of scenarios. In the reference scenario, demand and, accordingly, the mix of vehicles produced remain unchanged. Particularly relevant is what the authors call the TECH scenario, in which a mix of BEVs, PHEVs and fuel cell vehicles (FCEVs) gradually replaces the dominance of ICEVs. Other scenarios refer to a continued dominance of ICEVs, the enforcement of PHEVs or FCEVs as the dominant technology or even a complete ban on ICEVs and their complete replacement by BEVs from 2030.

In the TECH scenario, BEVs account for 10 per cent, PHEVs for 20 per cent and hybrid electric vehicles (HEVs) for 11 per cent of new registrations in Germany in 2030. In 2040, the share of BEVs grows to 49 per cent of new registrations while PHEVs and HEVs together reach 18 per cent of the market. The number of new annual registrations is assumed to be between 2.8 and 3.0 million vehicles, which is slightly below the 2016 level. The export and import ratio is kept constant (assuming no change in the global market position of German automotive companies) and production in Germany remains largely stable. It is assumed that the battery cells for BEVs are manufactured in Asia but assembled in Germany.

The exact cause-and-effect relationships of the model are difficult to trace. For the automotive industry, the model arrives at an employment increase of 28 000 jobs by 2030. After 2030, however, the effects are negative because of the increasing share of BEVs, reaching a loss of about 5000 jobs by 2040. For the German economy as a whole, however, there is an employment gain of 145 000 jobs by 2030 and, even after 2030, the further transition to electromobility turns into positive employment effects. These jobs are created throughout the economy as a result of the growth impetus generated by effects such as decreases in the cost of petroleum imports for fuel production.

– 'Electromobility 2035' (*Elektromobilität 2035*) (Mönning et al. 2018)

This study uses a macroeconomic input-output model that was developed for the analysis of labour demand by industries, as well as occupations and levels of requirements. The reference year is 2018, when employment in the automotive industry reached 830 000 people, production reached 5.1 million vehicles and the number of new vehicle registrations in Germany reached 3.4 million.

As with all studies based on economy-wide input-output models, this study's analyses incorporate a variety of assumptions, not all of which are reproduced in detail here. First, the central assumptions include long-term stability in the demand for automobiles. Regarding the transition to electromobility, the study assumes that around 600 000 BEVs will be registered annually in Germany by 2035, which would correspond to a share of around 23 per cent (the share of PHEVs is not taken into account). It is assumed that Germany will become a lead supplier for electromobility, which means that today's high export rate for ICEVs will also apply to BEVs. The import share of new registrations that apply to ICEVs will also apply to BEVs. Another key assumption is that the share of intermediate input imports for battery production will remain stable over the period studied; that is, battery components will continue to be sourced predominantly from abroad. Regarding annual productivity increases, it is assumed that these will gradually decrease from 4 per cent to 1 per cent for ICEVs over the period studied. For BEVs, annual productivity increases are assumed to be regularly 50 per cent higher. Overall, therefore, this is a rather conservative scenario.

Although the transition initially has positive effects on employment in the analytical model, the negative effects increase after a few years. For the German economy as a whole, the transition is expected to result in a loss of about 70 000 jobs by 2030, with losses increasing to 114 000 jobs by 2035. The majority of the losses concern jobs directly located in the automotive industry: about 50 000 by 2030 and about 83 000 by 2035.

– **'Automotive value creation 2030/2050' (*Automobile Wertschöpfung 2030/2050*) (Kaul et al. 2019)**

This study addresses both the consequences of electromobility and those of the further development of autonomous driving, although we focus here on electromobility. Within the framework of the model, a variety of factors are taken into account, such as the development of battery production costs, government subsidies for EVs, the roll-out of charging infrastructure and trends in productivity, exports, imports and other factors.

The starting point of the study is 2017, here with an employment level of 920 000 people in the German automotive industry and production at 5.6 million vehicles. To calculate the impact of electromobility, the study uses Bauer et al.'s (2018) analyses as a starting point. The disappearance of the internal combustion engine and its associated components eliminates a significant portion of the value added to the vehicle. Although new value added is produced in the area of the battery and the electric motor, this is lower than for the combustion engine and does not take place in Germany, particularly when it comes to battery cell production. However, the authors expect that additional value creation will be required for EVs compared with conventional drives, particularly in the area of electrics and electronics, but also in other areas (including the chassis). For example, the authors (Bauer et al. 2018: 124) expect that the value added for a BEV produced in 2028 will be about 10 per cent lower than for a vehicle with an internal combustion engine produced in 2017.

Regarding electromobility, the authors distinguish between two scenarios. In the conservative reference scenario, CO_2 emission targets for vehicle fleets lead automobile manufacturers to develop their EVs further, but persistently high battery prices and the lack of a sufficiently developed charging infrastructure slow down the diffusion of EVs. New registrations in Germany remain relatively constant at a level of 3.3 million vehicles until 2035, while production will rise (because of increasing exports) to 6.5 million vehicles in the same period. The share of BEVs in production increases to 27 per cent by 2030 and to 42 per cent by 2035 (PHEV 11 per cent in 2030; 8 per cent in 2035). This leads to a reduction in employment in the automotive industry of 110 000 jobs by 2030.

In the 'increased electrification' scenario, the rapid development of battery technologies (with falling prices) and the rapid expansion of the charging infrastructure lead to the BEV share of production reaching 34 per cent by 2030 (another 13 per cent are PHEVs), rising to 48 per cent by 2035 (and falling to 10 per cent for PHEVs). This scenario also assumes largely constant new registrations (about 3.3 million vehicles in 2035) and rising production (6.5 million vehicles in 2030).

Again, 110 000 jobs are lost by 2030 (and about 130 000 by 2035). In addition, employment is expected to be lost in the vehicle repair shop sector because the maintenance of EVs is less labour-intensive than that of traditional internal combustion engines.

– **'Employment effects of sustainable mobility' (*Beschäftigungseffekte nachhaltiger Mobilität*) (Schade et al. 2020)**

This is a follow-up study that builds on Schade et al. (2014). It uses the same macroeconomic input-output model to quantify the macroeconomic employment effects of changes in transport systems. The reference date is 2035 and the focus here is on three different mobility scenarios: a reference scenario as a continuation of the status quo (reference year 2015); a multimodality scenario in which rail becomes the dominant mode of transport; and an 'e-road' scenario in which the automobile remains dominant but a radical shift toward electromobility takes place. In this scenario, which we focus on here, the share of BEVs reaches 90 per cent of production in 2030.

In contrast to Schade et al. (2014), no specific assumptions are made for the import of inputs for electromobility technologies, but the growth rates for different types of imports and exports (bulk, general cargo, container goods) are estimated based on 1995-2015 data. Only exports of passenger cars and electric, communications and electronic components from Germany are modelled based on specific assumptions about the development of the vehicle fleet. The model includes an exogenously given productivity growth constant which, however, is not specified in more detail.

In the model, the number of passenger cars produced in Germany remains largely constant between 2018 and 2035. However, the share of midrange, luxury and premium vehicles increases from 53 per cent in 2020 to 74 per cent in 2035 – hence, vehicle prices rise, reinforcing the previous trend toward specialisation in the German automotive industry. The transition to electromobility requires massive investment.

Compared with the status quo scenario, the ‘e-road’ scenario will, according to the model’s assumptions, require additional investment of 18 billion euros in R&D and the production of batteries and chips by 2035, 70 billion euros in the rail and bus system (mainly trains and buses), 476 billion euros in the transport network (mainly the rail network) and 123 billion euros in transport power supply (charging stations, network expansion for electromobility).

Overall, the model arrives at positive employment effects regarding the transition for the German economy. By 2035, there is an increase of 1.2 million jobs across sectors compared with 2018 levels. Much of this job growth is found in the construction, energy supply, mechanical engineering and electronics sectors (because of the massive infrastructure investment). In automotive manufacturing, employment increases by 6000 by 2035. Behind this is a loss of 136 000 jobs in vehicle manufacture (chassis, powertrain, internal combustion engines and others) alongside the creation of 83 000 new jobs in battery and electric engine production, 48 000 in digital driver assistance systems and 12 000 in vehicle integration.

Chapter 6
The transition to the production of electric vehicles in Czechia and Slovakia

Petr Pavlínek

1. Introduction[1]

This chapter aims to analyse progress in the transition to the production of electric vehicles (EVs) – battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) – in the automotive industry of Czechia and Slovakia. It considers this transition in the context of the position of Czechia and Slovakia in the integrated periphery of the European automotive industry. It argues that the transition will be slower in Czechia and Slovakia than in western Europe and that both countries will continue to produce internal combustion engine vehicles (ICEVs) for longer than vehicle assembly factories in western Europe. The chapter draws on government documents, annual reports of carmakers and information collected from various local and international media to map the contemporary state of the automotive industries in Czechia and Slovakia, including their likely development in the foreseeable future. It also draws on previous empirical research conducted by the author in both countries, which included firm-level interviews and surveys of automotive industry firms in both Czechia and Slovakia prior to the onset of the transition to the production of EVs.

Section 2 provides an overview of the current state of the industry in both Czechia and Slovakia, examining their structures, employment and positions in the European context. In Section 3, transition pathways to the production of EVs in the integrated periphery of the European automotive industry are discussed with specific reference to Czechia and Slovakia. Sections 4 and 5 analyse how the transition to the production of Evs in each country is evolving by focusing on assembly firms (Škoda, Hyundai and Toyota in Czechia; and VW, Stellantis, Kia and Jaguar Land Rover in Slovakia), efforts to attract a battery gigafactory, government policies on electromobility and the effect on jobs of the transition. Finally, the main points of the chapter are summarised in the conclusion.

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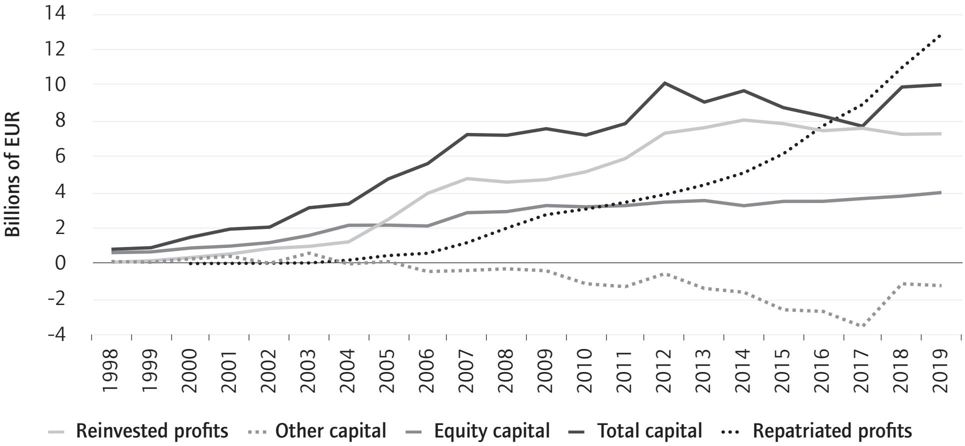
2. The current state of the automotive industry in Czechia and Slovakia

2.1 The position of Czechia in the European automotive industry

Based on the volume of production of vehicles and components, the number of employed workers and other indicators, the automotive industry of Czechia ranks among the largest in east-central Europe[2] and the European Union (EU). In 2020, Czechia's vehicle production of 1.16m vehicles was the fourth largest in the EU (after Germany, Spain and France) and the sixth largest in Europe (including Turkey). This strong absolute position of Czechia within the European industry based on the volume of production has grown gradually since the early 1990s, based on large inflows of foreign direct investment (FDI) (e.g. Pavlínek 2017a, 2008, 2015a) (Figure 1).

Figure 1 **FDI stock in the automotive industry (NACE 29) of Czechia, 1998-2019**



Source: Compiled by author based on data in CNB (2022).

FDI has been attracted by a combination of low labour costs compared to western Europe, large investment incentives, low corporate taxes, geographic proximity to western European markets and EU membership. Interviews with 69 foreign-owned automotive firms in Czechia revealed that low labour costs were listed as the leading competitive advantage by 84 per cent of those interviewed (Pavlínek 2020).

Changes in the total stock of FDI, which peaked in 2012, reflect changes in annual FDI inflows. Between 2012 and 2019, however, annual FDI inflows decreased except for 2018. Annual inflows of equity capital have not exceeded 200 million euros annually and amounted to only 761 million euros between 2012 and 2019. Reinvestments were the most important source of inflows during this period, totalling 3.7 billion euros,

2. For reasons of in-volume consistency, we have adopted the terminology of central and eastern Europe (CEE) in the rest of this chapter.

but they also decreased considerably in 2018 and 2019.The repatriation of profits grew constantly during the period.

2.1.1 Specialisation and the structure of production

The automotive industry in Czechia is highly specialised in the export-oriented production of passenger cars (henceforth cars) and car components. In 2020, Czechia was the 11th largest exporter of cars by value (20.8 billion dollars) in the world (WTEx 2021). Most of the vehicles assembled in Czechia are for export: in 2019, 92.5 per cent of production was exported, including 92.5 per cent of cars and 95.4 per cent of buses (AIA 2022). This suggests a very high dependence on external markets, one of the basic features of the integrated peripheries of the contemporary automotive industry (Pavlínek 2018, 2020).

The industry is dominated by foreign capital. In 2019, the index of foreign control stood at 93.0 (100 meaning total dependence on foreign capital) and was the fourth highest in Europe after Slovakia, Hungary and Romania. Foreign firms accounted for 95.6 per cent of turnover and 95.7 per cent of the production value in 2019 (Eurostat 2021b).

Czechia has three foreign assembly firms producing passenger cars: Škoda Auto, which is owned by German Volkswagen; the Japanese firm Toyota; and South Korea's Hyundai. Toyota has an assembly factory at Kolín in Central Bohemia, while Hyundai's assembly factory is located at Nošovice in the north-eastern part of Czechia (in the region of Moravia-Silesia). In 2019, Škoda Auto assembled 907 942 cars in Czechia (749 579 in 2020); Hyundai assembled 309 500 vehicles (238 750 in 2020); and Toyota 210 121 (164 572 in 2020) (AIA 2022).

Toyota and Hyundai specialise in the export-oriented assembly of small and compact models. Toyota produces the Aygo, its smallest and cheapest entry model in Europe, although it also started to assemble the Yaris in November 2021. Toyota will continue to produce both models based on the same GA-B platform at Kolín in the future. Hyundai produces the Tucson, a compact crossover SUV, which accounts for two-thirds of the output of Nošovice; the Hyundai i30 and the Kona Electric, which has been assembled since 2020, account for the remaining one-third. Hyundai also makes manual transmissions at Nošovice.

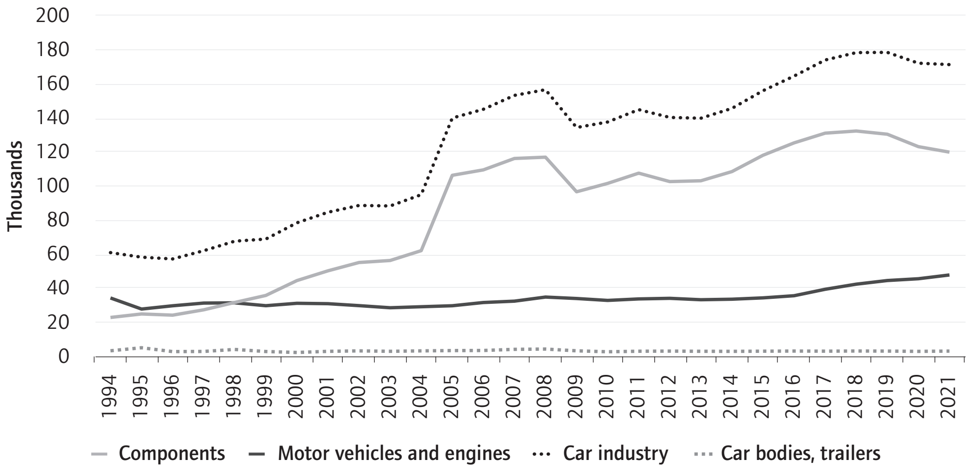
Škoda Auto has a more diverse portfolio of models made in Czechia because it is one of the mass-market brands within the VW Group. In addition to small models, such as the Fabia and the Rapid, it also produces midsized models such as the smaller Octavia, the larger Superb and three SUVs: the Kamiq (a subcompact crossover SUV); the Karoq (a compact crossover SUV); and the Kodiaq (a midsize crossover SUV). Since 2020, Škoda Auto has also assembled the fully electric car, the Enyaq, in Czechia.

2.1.2 Employment

Employment in the automotive industry has increased steadily since the mid-1990s because of the large inflows of FDI that led to the rapidly expanding production of cars and buses (Figure 2). Between 1994 and 2019, the average number of employees in the narrowly defined industry[3] almost tripled, from 61 000 in 1994 to 179 000 in 2019.[4] However, there are important differences between different segments within the industry.

The growth in employment has been driven by the manufacture of parts and accessories for motor vehicles and their engines (NACE 29.3), which increased the number of workers by more than five and half times between 1994 and 2019, adding more than 100 000 jobs (a total of 23 000 in 1994; 131 000 in 2019) as Figure 2 shows. At the same time, employment in the assembly of motor vehicles and engines (NACE 29.1) expanded marginally while that in the manufacture of trailers and semi-trailers (NACE 29.2) stagnated at a low level. In addition to the 179 000 direct jobs in the narrowly defined automotive industry there are approximately 500 000 indirect ones (Deloitte 2021).

Figure 2 **Change in the average number of registered employees in the automotive industry of Czechia (1994-2019)**



Note: 1994-2004 data: NACE 34; 2005-2019 data: NACE 29.
Source: Author based on data in MIT (various years).

Automotive firms have faced serious labour shortages in Czechia. In each year since 2017, the national unemployment rate has been below 3 per cent (2.9 per cent in 2017; 2.2 per cent in 2018; 2.0 per cent in 2019; 2.6 per cent in 2020; and 2.7 per cent in 2021). Central Bohemia, which hosts the main production complex of Škoda Auto in Mladá Boleslav, the Toyota factory in Kolín and many component suppliers, records a consistently lower unemployment rate than the national average. Similarly, the region

3. NACE 34, used until 2008, refers to the NACE Rev. 1.1 classification of the automotive industry and NACE 29, introduced in January 2009, refers to its NACE Rev. 2 classification. These two classifications are not fully compatible because of their slightly different composition.
4. Actual direct employment in automotives is larger as the broadly defined industry also includes firms from other industrial sectors that are involved in the automotive value chain but are not included in NACE 29, such as suppliers from the plastic industry, rubber industry, electrical equipment and the iron and steel industry.

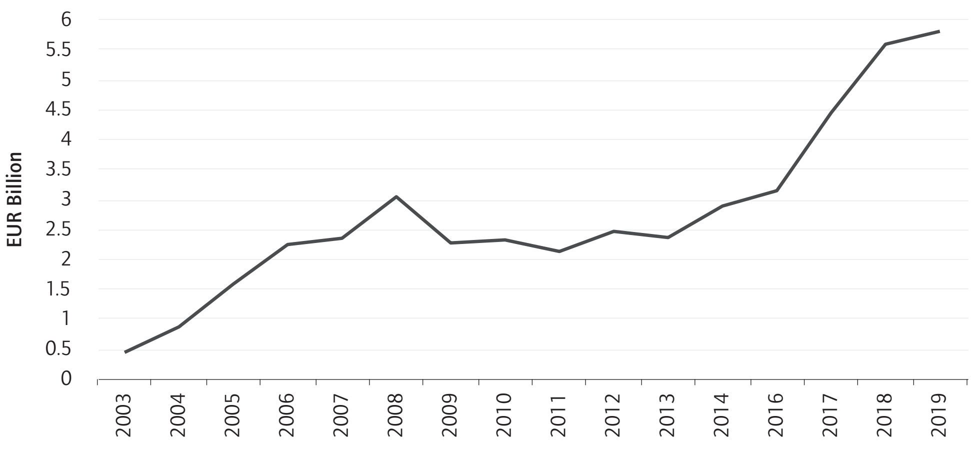
of Hradec Králové, which hosts the second Škoda assembly complex at Kvasiny and the Škoda factory at Vrchlabí, also records a below average unemployment rate. The Moravia-Silesia region, where the Hyundai factory is located, has a slightly higher unemployment rate than the national average but it has still been very hard for automotive firms to find the workers required. Labour shortages have forced them to rely increasingly on foreign workers and agency employment, but also to embark on automation. They have, in addition, improved the bargaining power of unions and led to higher wage increases. However, they have also limited the future growth potential of the country's automotive industry.

In addition to jobs, the crucial importance of the industry for the national economy is also reflected in that it accounts for 26 per cent of value added in the Czech manufacturing industry and 23 per cent of Czech exports (32.98 billion euros in 2020). The automotive industry also accounts for more than one-third of spending on industrial R&D (Deloitte 2021).

2.2 The position of Slovakia in the European automotive industry

Despite its automotive industry having a limited tradition compared to Czechia (Pavlínek 2008, 2017a), Slovakia's has grown very rapidly since the late 1990s (Pavlínek 2016, 2018). Slovakia produced no vehicles in 1990, but it ranked eighth among European countries and sixth in the EU in total vehicle production in 2019 and 2020. As in the case of Czechia, the rapid growth of the automotive industry in Slovakia has been based on an influx of FDI (Figure 3), attracted by low wages, investment incentives, a large labour surplus in the early 2000s, low corporate taxes and geographic proximity to western Europe.

Figure 3 **FDI stock in the automotive industry (NACE 29) of Slovakia, 2003-2019**



Note: 2015 data not available.
Source: Compiled by author from data in NBS (2022).

These location factors attracted several flagship investments in car assembly in the 2000s and 2010s, namely PSA Peugeot Citroën (nowadays Stellantis), Kia and Jaguar Land Rover (JLR); and also led to the large expansion of VW's operations that had originally been established in the early 1990s (Pavlínek 2016, 2018). These flagship investors in turn attracted component suppliers, with many being attracted by low wages and the labour surplus in Slovakia to set up the production of parts and components oriented towards exports (Pavlínek 2018). Based on interviews with 29 foreign-owned automotive firms in Slovakia in the 2010s, follow sourcing (45 per cent), low production costs (i.e. low wages) (41 per cent) and the policy of the very aggressive investment incentives being offered by the Slovak government (28 per cent) were the three most important reasons for investment in Slovakia. The country's low labour costs[5] were listed (by 85 per cent of interviewed firms) as the industry's most important competitive advantage by far (Pavlínek 2018).

In addition, Volvo will be the fifth car manufacturer in Slovakia, having announced a 1.2 billion euros investment in an electric car assembly plant in eastern Slovakia, due to start operation in 2025 (Atena 2022).

In contrast to Czechia, following decline and stagnation between 2008 and 2013 due to the global economic crisis, the stock of FDI in the automotive industry (NACE 29) has continued to grow strongly since 2013, as Figure 3 shows, although FDI inflows did slow in 2018 and 2019. This growth was, in particular, the outcome of the JLR investment, reflecting the 1.4 billion euro assembly factory opened in 2018, and FDI by JLR suppliers. Meanwhile, VW Slovakia also continued to invest in Slovakia in the second half of the 2010s.

Since 2007, Slovakia has had the largest per capita production of cars in the world (182 cars per 1000 inhabitants in 2020; 202 in 2019). More importantly, the industry is almost totally controlled by foreign capital, with the country recording consistently the highest values of the index of foreign control in Europe: in 2019, 98.1 per cent was under foreign ownership and control. The Slovak economy is heavily dependent on the automotive industry which accounted for 51.5 per cent of manufacturing in 2020 and 53 per cent of total manufacturing exports, as well as 14.9 per cent of GDP (ZAP 2021a).

2.2.1 Specialisation and the structure of production

The automotive industry is 100 per cent specialised in the export-oriented production of passenger cars; there was no production of heavy trucks, light commercial vehicles or buses in 2019 and 2020 (OICA 2021). Four car assembly firms account for all vehicle production: German-owned VW; French-owned Stellantis; South Korean-owned Kia; and Indian-owned Jaguar Land Rover. The structure of production by carmaker in 2019 and 2020 is shown in Table 1.

5. Wages were 86 per cent lower than in Germany in 2001 and the lowest in central Europe in the early 2000s. There was also a large labour surplus induced by Slovakia having the highest unemployment rate in central Europe in the early 2000s, standing at 19.5 per cent in 2001.

Table 1 **Vehicle production by carmaker in Slovakia in 2019 and 2020**

	2020	2019
VW	309 348	377 750
Stellantis	338 050	371 152
Kia	268 200	344 000
JLR	69 402	15 000
Total	985 000	1 107 902

Note: The JLR figures were calculated as the difference between the total for Slovakia reported by OICA (2021) minus the sum for VW, Stellantis and Kia.
Source: VW (2021); Stellantis (2021); Kia (2021); OICA (2021).

Assembly firms have specialised in two types of production in Slovakia: the mass production of small cars and the labour intensive low volume assembly of luxury models (Pavlínek 2002). Stellantis is making the Peugeot 208, a small subcompact car, and the Citroën C3, a supermini. Kia produces small compact cars: the Ceed (a small family car); the Sportage (a compact crossover SUV); and the Venga, a mini multi-purpose vehicle. In the case of VW, the production of small cars (VW up!, Škoda CITIGO and Seat Mii) (25 per cent of VW Slovakia's output) takes place along with the labour intensive assembly of luxury models (VW Touareg, Audi Q7 and the Porsche Cayenne) that accounted for almost 75 per cent of its output in 2020. JLR started the low volume production of luxury SUVs in Slovakia in 2018 (the Land Rover Discovery and Land Rover Defender).

As in the case of Czechia, most vehicles are for export. More than 99 per cent of the cars assembled by VW Slovakia and more than 98 per cent of those of Kia Slovakia were exported in 2020 (VW 2021; Kia 2021); while more than 90 per cent of the production of Stellantis went to the EU market the same year (Stellantis 2021). In 2020, Slovakia was the tenth largest exporter of cars in the world based on value (WTEx 2021).

2.2.2 Employment

The rapid development of the automotive industry in Slovakia translated into a rapid growth in employment. In 1993, the industry employed 6000 workers (Pavlínek 2016) but, by 2018, the number employed in the narrowly defined industry (NACE 29) reached 80 963 (Eurostat 2021b). Including indirectly generated jobs, the industry employs more than 270 000 workers (ZAP 2021a).

As in Czechia, the largest share of jobs is in the manufacture of parts and accessories for motor vehicles and their engines, which accounted for between two-thirds and three-quarters of the total from 2008 to 2019. The share of vehicle assembly jobs (NACE 29.1) increased from one-quarter to one-third with JLR opening its new factory in 2018 and VW increasing production. VW Slovakia is the largest automotive employer in the country, employing 11 500 workers in its three factories in 2020 (at Bratislava – vehicle assembly; Martin – components for gearboxes and chassis, differentials, synchronous rings and different types of shafts; and Stupava – welding pliers, robotic grippers, fixtures and protective devices (VW 2021)). Stellantis employs about 4500 workers near the city of Trnava; Kia employed 3670 workers at its factory located close to Žilina in 2021; and JLR employed 1500 workers at Nitra in 2018 and almost 4000 in 2021, while it announced the creation of an additional 600 new jobs for 2022 (Turza 2021). Better labour supply was among the location choice criteria of Volvo Cars in setting up its electric car factory in eastern Slovakia (Atena 2022).

As in Czechia, the rapid growth of the automotive industry due to the large influx of FDI since the early 2000s exhausted the labour surplus and lead to labour shortages by the middle of the 2010s. Nationally, the unemployment rate fell from 19.5 per cent in 2001 to 14.2 per cent in 2014, and thereafter to 5.8 per cent in 2019 and 6.7 per cent in 2020. This was especially the case in western Slovakia which, particularly along the Bratislava-Žilina corridor, has been the most popular destination for automotive FDI (Eurostat 2021d; Pavlínek 2016; Jacobs 2016). In 2001, the unemployment rate in West Slovakia (NUTS 2) was 17.49 per cent but this had declined to just 2.93 per cent by 2019 (SSO 2022).

The very low unemployment rate has translated into severe labour shortages for automotive firms in western Slovakia and is a barrier to the further development of the industry. In 2018, 82 per cent of the 61 automotive suppliers surveyed in Slovakia identified the lack of available qualified workers on the job market as a risk factor affecting their future growth prospects, 78 per cent considered the unavailability and low quality of labour a major issue for their company and 53 per cent (up from 37 per cent in 2016) argued that the lack of skilled labour restricted their ability to win or accept new contracts (PwC 2018).

3. Transition pathways for the production of electric vehicles in the integrated periphery of the European automotive industry with a focus on Czechia and Slovakia

The automotive industry of Czechia and Slovakia is part of the integrated periphery of the European automotive industry (Pavlínek 2018, 2020, 2022). Pavlínek (2018: 144) defines an integrated periphery as:

> A dynamic area of relatively low-cost (industrial) production that is geographically adjacent to a large market and has been integrated within a core-based macro-regional production network through FDI. In an integrated periphery, production, organization, and strategic functions in a given industry are externally controlled through foreign ownership.

Accordingly, Pavlínek (2018, 2020) identified the basic features of the integrated periphery of the European automotive industry as follows:

1. Substantially lower wages than in the core regions (Pavlínek 2022); see also Table 2.[6]
2. A sizeable labour surplus in the initial stages which, however, becomes exhausted over time because of the rapid growth of the industry due to the influx of profit-seeking FDI.
3. Geographic proximity to big and profitable markets and EU membership or preferential trading arrangements with the EU.
4. A high degree of foreign ownership and control through FDI.
5. An overwhelmingly export-oriented production focusing on standardised cars, niche market vehicles and generic automotive components.
6. The underdevelopment of high value added and strategic functions, such as R&D and strategic decision making, compared to the extent of production functions and in comparison with core regions (Pavlínek and Ženka 2016; Pavlínek 2016, 2022), leading to truncated development in the periphery (Pavlínek 2017b).
7. FDI-friendly state policies including low corporate taxes and large investment incentives in competition with other countries within the integrated periphery over strategic automotive FDI leading to a 'race to the bottom' (Pavlínek 2016).
8. Weak labour unions, more liberal labour codes and more flexible labour practices compared to core countries (Drahokoupil and Myant 2017).
9. A small and weakly developed domestic industry compared to the foreign-controlled sector.
10. The integration of the majority of domestic firms into macro-regional production networks at an inferior and subordinate position, mainly as low cost tier three suppliers of niche products (Pavlínek and Žížalová 2016).

Table 2 **Annual labour costs per employee (full-time equivalent in thousand euros, at exchange rate parity) in the European automotive industry (NACE 29) by country in 2019**

	Thousands of euros	Germany = 100
Germany	87.9	100.0
France	71.2	81.0
Spain	47.4	53.9
Czechia	26.0	29.6
Slovakia	25.2	28.7
Hungary	23.0	26.2
Poland	19.4	22.1
Romania	14.5	16.5

Source: Eurostat (2021b).

This relative position of the European automotive industry's integrated periphery, including Czechia and Slovakia, will strongly influence the course of the transition to the production of EVs and their components, and will have consequences for national and

6. In 2001, average personnel costs (personnel costs per employee) in the automotive industry (NACE 29) were 85 per cent lower in Czechia than in Germany and 86 per cent lower in Slovakia. Average personnel costs were lower (again using Germany as the comparator) by 95 per cent in Romania, 84 per cent in Poland, 82 per cent in Hungary and 96 per cent in Bulgaria (Eurostat 2016).

regional economic outcomes. The overarching hypothesis of this chapter is that the transition of the industry in Czechia and Slovakia to the production of EVs is inevitable; the question is only one of its speed, i.e. how long it will take and how it will ultimately affect the shape of the industry in both countries. However, this hypothesis of the inevitability of such a transition is not necessarily shared by many politicians, industry experts and the media in Czechia and Slovakia who question the rationale for the transition.

The transition to electromobility will have significant effects on the automotive industry in both Czechia and Slovakia, where major restructurings affecting the composition of the industries and employment are likely. The transition will, in particular, affect the production of parts and components (NACE 29.3), the largest employer in the industry in both countries. However, it will also affect the manufacture of vehicles and engines (NACE 29.1) since the production of electric engines is less labour intensive than the manufacture of internal combustion engines (ICE) (CLEPA 2021; Bauer et al. 2020).

This transformation of the industry will have very uneven effects on the supplier industry. On the one side, suppliers of components and parts for the ICE powertrain (e.g. components and parts for engines, gearboxes, fuel lines and exhaust systems) will be most affected. On the other, there are large segments of the supplier industry that are unrelated to ICE and which will see few effects or none. Czechia and Slovakia are less specialised in ICE production than neighbouring Poland and Hungary, despite each having one engine factory (Škoda Auto in Czechia; and Kia Slovakia). Additionally, Czechia has two factories making gearboxes (one at Škoda Auto at the Vrchlabí plant and the other at Hyundai Nošovice), while Slovakia has one at VW Slovakia in Bratislava and also a significant production of components for gearboxes at the Martin factory (VW 2021).

But, even in the case of ICE, production will not necessarily end in 2035 because Škoda Auto and its suppliers are likely to continue with respect to foreign markets that will undergo a much slower transition to electromobility such as India, Russia, South America and north Africa. The speed of the transformation will also vary in different segments of the supplier industry. In most cases, the change will not be abrupt but gradual. Therefore, the automotive industry in both Czechia and Slovakia will have enough time to prepare and restructure production towards the production of EVs.

Neither country is, and neither will be, a centre of innovation for electromobility. R&D for the transition to EVs is mainly taking place in the home countries of assembly firms and the largest 'global' tier one suppliers. Škoda Auto might be a partial exception because it is a distinct brand and a tier two lead firm[7] within the VW Group (Pavlínek and Janák 2007; Pavlínek 2012, 2015c) with some potential to become an important player in the field. Tier two lead firm position within the VW Group means that Škoda Auto does have important R&D competencies, including ones related to the transition to EVs (Škoda Auto 2021c), although these are much smaller than those carried out at VW's main corporate R&D centre.

7. A tier two lead firm has a significant autonomy to produce, manage and develop a distinct brand within the group.

The R&D competencies that are found at Škoda Auto are usually absent in foreign-owned assembly branch plants, including the Toyota and Hyundai branch plants in Czechia and in all assembly factories in Slovakia, a typical feature of truncated development. These high value added activities tend to remain concentrated in the home countries of foreign investors, usually at corporate headquarters and corporate R&D centres (Britton 1980, 1981; Hayter 1982; Pavlínek 2017b). Problems related to this, such as the negative consequences for the potential of indigenous technological development in peripheral regions or value transfer from peripheral to core regions, would be most pronounced in industries or economies with a very high degree of foreign ownership and control, as is the case in Czechia and Slovakia (Pavlínek and Ženka 2016; Pavlínek and Žížalov 2016; Pavlínek 2012, 2016, 2018).

In core-periphery regional systems, innovations do gradually, but selectively, spread from the core areas to peripheral ones (Friedmann 1967). Innovation related to R&D in electromobility, especially in the production of EVs, will thus spread to the integrated peripheries. However, the intensity and size of this innovation will continue to be much stronger in the core areas than in the integrated periphery because of the much better conditions for innovation in the core (Isaksen and Trippl 2017).

Furthermore, while fully dedicated factories for the large-scale production of EVs have already been opened in western Europe (e.g. VW's factories at Zwickau and Emden), fully dedicated EV factories have not yet been opened in Czechia or Slovakia whose factories will be producing EVs alongside ICEVs, which will make it more difficult to achieve scale economies and, therefore, lower production costs for EVs. Carmakers plan to compensate for this deficiency with lower production costs and high labour flexibility to make this kind of mixed production viable in the short and, perhaps, the medium term. In the long run, however, this strategy is not competitive compared to fully dedicated EV factories in which each assembly line is fully dedicated to one platform (Gibbs 2019). Therefore, the strategy of mixed production may become a major disadvantage.

In some cases, the production of ICEVs is actually being transferred to Czechia and Slovakia: for example, VW is transferring the VW Passat to Slovakia to make space in Germany for the production of EVs (VW 2021). There are several reasons why this would be the case: newer, more modern factories in CEE compared to western Europe; older technologies continue longer in peripheral locations than in core locations according to the product life cycle model (Vernon 1966); and the whole region has lower labour costs than in western Europe (Table 2). Additionally, transition to the production of EVs will mainly be driven by foreign rather than by domestic demand. Not only are more than 90 per cent of cars produced both in Czechia and in Slovakia exported; more importantly, demand for EVs has been extremely low in both countries. It also makes sense for carmakers to continue to make ICEVs close to the markets in which they also will be sold.

For all these reasons, we may assume that the transition to the production of EVs will thus be slower than in western Europe, in particular than in the core countries of the European automotive industry production system (Germany, France and Italy), and that the integrated periphery will be the last region in the EU to shut down the production of ICEVs completely. Thus, production may well continue for one or two decades longer, in spite of the agreement reached by the European Parliament (2022) and the Council confirming the 100 per cent emissions reduction target for new cars and vans by 2035. However, relying on the continuing production of ICEVs (even for non-EU export) is a risky strategy because delays in the introduction of the large volume, mass production of EVs might undermine the long-term competitiveness of the domestic industries compared to those in countries and regions that undergo a rapid transition to the production of EVs.

Many suppliers based in Czechia and Slovakia, both foreign-owned and domestic, are also engaged in the export-oriented manufacture of ICE components for EU countries. These suppliers will soon face declining orders due to the rapid transition to the production of EVs in western Europe and, therefore, job losses are very likely, despite the slower transition. Domestic firms in both countries, being mostly captive tier three or niche suppliers, are in a weak position to affect any changes related to the transition and will not be a driving force in it. They might become even more marginalised in the course of this transition because they often lack R&D capabilities and therefore have a low absorptive capacity, making it difficult for them to take on board new technological innovations (Pavlínek 2018).

Given the extremely high degree of foreign control, the automotive industries in Czechia and Slovakia are in a strongly dependent position on foreign capital. Their future will thus be decided abroad by large foreign-owned assembly firms and suppliers through corporate decisions about the allocation of production and investment. The weak role of the state in the transition to the production of EVs in both countries (see also below) further reinforces this assumption.

In particular, the transition to the production of EVs will particularly depend on the success of VW, the largest carmaker in both countries. We might thus expect strong negative effects on the domestic economies in the unlikely case of the failure of VW to transition successfully to the production of EVs. Other foreign firms have already started to launch the assembly of EVs in both countries or are planning to do so. Such transitions will be faster in those cases where these cars are a distinct brand within a large multinational (such as Škoda within the VW Group) or where an assembly factory in Czechia or Slovakia is the only one they have in the EU (such as Hyundai and Kia). The Toyota factory does not fall into either of these two categories. Therefore, we may expect a slower introduction of the assembly of EVs in the case of Toyota than in the case of the assembly factories of other carmakers.

A slow transition to EVs might also weaken the position of Czechia and Slovakia in the international division of labour in the European automotive industry. This will additionally be the case if they fail to secure the location of battery gigafactories on their territories. Attracting FDI to battery and cell manufacturing is a feasible strategy to attract the assembly of EVs. Since batteries are heavy, geographic proximity lowers the costs involved in transporting finished batteries to a vehicle assembly factory. Foreign-owned EV battery production plants have been built in Hungary and Poland, but not yet in Czechia and Slovakia (although Škoda Auto does have an EV battery assembly line, as does Stellantis in Slovakia). It is not surprising that both Czechia and Slovakia would like to attract battery production and catch up with Hungary and Poland, even though jobs in EV battery assembly are not high value added ones.

Czechia and Slovakia will continue to have strong location advantages for the automotive industry, including low wages, a geographic location close to the large and affluent west European market and EU membership, meaning that they will continue to be attractive for potential new EV assembly plants and the production of battery cells and components (Pavlínek 2020).

Nevertheless, this growth potential can be undermined by the insufficient or exhausted labour surplus, as has recently been the case particularly in Czechia (Pavlínek 2015b; PwC 2019). Labour can be imported from abroad and is often cheaper than the domestic workforce (Andrijasevic and Sacchetto 2014) as well as an important source of numerical flexibility for automotive firms in the form of temporary agency employment (Drahokoupil et al. 2015). In general, however, labour shortages increase competition in the labour market for available and existing workers, leading to rising wages and, in turn, undermining the rate of profit and future growth as potential investors start looking elsewhere for investment opportunities (Pavlínek 2018, 2020). It may also undermine the competitiveness of existing firms, especially those engaged in labour intensive activities such as the assembly of cable harnesses.

4. The production of electric vehicles, plug-in hybrids and batteries in Czechia

Having discussed the transition pathways to electromobility, this section will summarise the development of the production of EVs in Czechia to date.

Škoda Auto and Hyundai have been assembling BEVs and PHEVs in Czechia. In contrast, Toyota had not started the assembly of either type at its Kolín factory before November 2021. However, with the launch of the assembly of the Toyota Yaris in November 2021, the assembly of its PHEV version of this model has now got underway.

4.1 Škoda Auto

Škoda Auto plans to reduce the CO_2 emissions of its fleet by more than 50 per cent between 2020 and 2030 (Randall 2021b). It also plans to achieve the CO_2 neutrality of all its factories in Czechia by 2030 in terms of the energy used to manufacture vehicles and components (Škoda Auto 2020; Randall 2021b).

Škoda aims to achieve 50-70 per cent EV sales by 2030, which will include introducing four entry-level BEV models into the market (Dunn 2021; Hampel 2021c). In 2016, Škoda was successful in gaining VW’s permission to produce Škoda EVs at its factories in Czechia based on VW’s Modular Electric Drive Matrix (MEB) platform.

Škoda's Mladá Boleslav main factory complex is one of eight MEB plants VW Group has selected worldwide and the only one in the region (four are in Germany and the remainder are in Anting/Shanghai and Foshan in China and Chattanooga in the US) (Hampel 2020a). The minicar Škoda CITIGOe, Škoda's first BEV, was introduced in 2019 (Randall 2021b) although production quickly ended and there are no plans for a relaunch (Jánský 2022). Instead, a new small BEV for the European market, costing less than 20 000 euros, is likely to be initially produced only in China by Volkswagen Anhui, the joint venture between VW and the Chinese manufacturer JAC. Eventual assembly in Europe, either in Spain or in Slovakia, will not start before 2025 (Hampel 2020c). All three BEVs that Škoda plans to introduce by 2030 will be smaller and cheaper models than the Enyaq iV (Randall 2021b).

The assembly of the Škoda Superb PHEV was launched at the Kvasiny factory in September 2019 (Škoda Auto 2020) and, in August 2020, Škoda began the assembly of the plug-in hybrid version of its most popular model, the Octavia, at Mladá Boleslav. It has also launched the Octavia model with compressed natural gas propulsion and mild hybrid technology (called e-TEC) (Škoda Auto 2021c). The first MEB platform-based Škoda model was the medium-sized SUV, the BEV Enyaq, which was introduced in September 2020 and whose assembly was launched in November of 2020 (Škoda Auto 2021c). Škoda does not have an MEB-dedicated assembly line for this model and it is assembled on the same assembly line as the Octavia (Hampel 2020b).

In 2021, Škoda assembled 49 701 BEVs, representing 7.3 per cent of its total production in Czechia, and 27 919 PHEVs, representing 4.1 per cent (AIA 2022).

In addition, the company produces batteries for VW Group's MQB platform. Its initial output was 150 000 batteries per year but is expected to grow in the future along with the increased demand for PHEVs (AMS 2019). Batteries for BEVs based on the MEB platform will be produced elsewhere, but Škoda Auto has announced the production of MEB battery packages for the Enyaq iV that started at the beginning of 2022.

To support the launch of its production of EVs, Škoda opened a technology centre in 2020, focusing on components and the training of new and existing employees in areas related to electromobility (Škoda Auto 2021c). Škoda originally launched a training programme for employees in May 2016 and, by the end of 2020, 16 521 workers had undergone training through the Škoda Academy and assembly training centres (Škoda Auto 2020, 2021c).

The strengthening of Škoda Auto's R&D competencies within the VW Group, even if this happens in the context of ICE technology, is a positive development. It was given responsibility for the continuing development of a new generation of ICE models, the VW Passat and Škoda Superb (Škoda Auto 2020) and for producing and developing smaller ICEVs for developing markets such as India, south-east Asia, South America, Africa and China (Škoda Auto 2021b). Škoda took over responsibility for the Indian market in 2018 and is also responsible for the north African market (Škoda Auto, 2019). Despite the transition to electric vehicles, VW Group expects continuing demand over the next decades for smaller and more simple ICEVs in less developed markets. Since

November 2021, Škoda Auto has been given global responsibility for the development of VW's MQB-A0 global platform, which will be the basis of small ICE models within the Group. Additionally, while this platform will not be suitable for BEVs, it will be developed with the possibility of hybridisation (Gibbs 2021). It is expected that up to 7.5 million VW Group cars will be assembled on this platform in the future. The transfer of the development of the MQB-A0 platform to Škoda Auto will create 'hundreds' of jobs in Škoda Auto's R&D centre (E15 2021). This amounts to an important functional upgrading because the last platform that Škoda developed was for the Favorit in the 1980s, well before its takeover by VW in 1991 (Pavlínek 2008). These increased R&D responsibilities are related to the main R&D centre of VW being fully focused on R&D for BEVs and PHEVs and to the division of labour within the VW Group., Still, the success of Škoda Auto's R&D centre in the development of the MQB-A0 platform might signal its R&D capabilities to VW and might lead to increased R&D responsibilities in the future in electromobility. As Škoda will produce PHEVs for developed affluent markets, with a responsibility for small BEVs for the VW Group (Randall 2021c), good performance in ICE-related R&D might also help with upgrading in EV competences.

At the same time, it has been reported that Škoda Auto will leave China, its largest and most important market since 2010. Currently, Škoda models are manufactured at four joint venture factories with SAIC Volkswagen in China. More than three million Škoda cars were assembled in China between 2007 and 2020 (Škoda Auto 2021c). The withdrawal of Škoda from China will lead to a geographical division of labour within the VW Group in which Škoda will take responsibility for markets that are not expected to transition to EVs in the foreseeable future and focus on the continuing development and production of ICEVs.

Overall, Škoda Auto seems best positioned to transition successfully to the production of electric cars in Czechia with a complete production cycle, including some R&D responsibilities and competencies not only for its factories in Czechia but for the VW Group as a whole. The main reason for the better position of Škoda than Hyundai or Toyota in Czechia is that Škoda is one of the VW Group distinct brands and its position as a tier two lead firm (Pavlínek and Janák, 2007; Pavlínek, 2012; 2015a).

4.2 Hyundai

Hyundai's factory in Nošovice is its only factory located in the EU. It began to assemble the Kona Electric crossover for the EU market in March 2020 as demand began to increase; previously, all Konas had been imported from South Korea (22 500 units in 2019) (Kane 2020). The batteries for the car are delivered from the South Korean-owned LG Chem battery cell factory in south Poland (Randall 2020a). The Kona is assembled on the same assembly line as the i30 and the Tucson. The assembly of the fourth generation Hyundai Tucson was also launched at Nošovice in 2020 and, in addition to the conventional combustion engine version, the Tucson is also available in mild hybrid (MHEV), hybrid (HEV) and PHEV versions (Hyundai 2020).

In 2021, the factory produced 43 642 electric vehicles of which 22 468 were BEVs and 21 174 PHEVs, constituting respectively 8.2 per cent and 7.7 per cent of the factory's total output (AIA 2022) and making the Czech plant Hyundai's largest foreign location outside South Korea for electric cars.

4.3 Toyota

Toyota is the only carmaker in Czechia that has not yet launched the assembly of BEVs. In January 2021, Toyota took over the former joint venture with Peugeot, known as TPCA. The Kolín factory produces mini cars for Toyota (the Aygo), Peugeot (the 107) and Citroën (the C1) for the European market. After the takeover, Toyota invested more than 180 million euros in starting the production of a second model, the Yaris, including the Yaris hybrid that started in Kolín in November 2021 (Dvořák 2021b).

4.4 Efforts to attract a battery gigafactory to Czechia

Compared to Poland and Hungary, independent foreign battery providers have not yet built any factories in Czechia and no location decisions had been announced as of 2022. The government recognises the absence of battery producing facilities as a potential threat to the future of the automotive industry in the country. Therefore, in July 2022, the Czech Ministry of Industry and Trade signed a memorandum with the government-linked energy company ČEZ in which they committed state support for the construction of a two billion euros 40 GWh gigafactory. ČEZ will be the main investor and will supply energy, lithium and land for the factory as, since 2020, it has owned lithium deposits in Cínovec, the largest in Europe (and up to 3 per cent of the global total) (Deloitte 2021). However, ČEZ lacks the necessary technology and know-how to build and operate the gigafactory alone, so it is seeking a foreign partner (Prokeš 2021b; Patricolo 2022). The gigafactory could make up to 800 000 batteries per year and employ 2300 workers (HN 2021) by the time of its estimated launch, sometime between 2026 and 2028, while input-output analysis by Deloitte (2021), identifies that it could create up to 39 000 new jobs in Czechia, including direct jobs and indirect ones in related industries.

The Czech government has promised to offer investment incentives, including tax breaks, for building the transportation infrastructure and retraining thousands of workers (Liebreich 2021).

Although the government planned to choose a foreign partner in 2021, and in October 2022 designated the location of the factory in the Plzen region, ČEZ still lacks a foreign partner (Patricolo 2022). VW has not yet decided on the location of its future CEE gigafactory although it has already decided on five others in Germany and western Europe.

4.5 Government policies and the transition to the production of electric vehicles in Czechia

To allow greater state support for the battery gigafactory, the government of Czechia has been preparing new rules for the direct state support of large strategic investments that would lower the requirements from 500 newly created jobs to 250 but increase the minimum investment from 0.5 billion koruna to two billion koruna, starting in 2022. State support would increase from a maximum of 10 per cent of investment costs to 20 per cent and the ceiling, which is currently at 1.5 billion koruna, would also be removed (Prokeš 2021a; Deloitte 2021).

Hitherto insufficient investment incentives in the eyes of potential investors (South Korean SK Innovation, Samsung SDI and LG Chem; and Chinese CATL), may have contributed to their decisions to build battery gigafactories in Hungary[8] and Poland and none in Czechia. The continuing emphasis on job creation in the offer of investment incentives to foreign firms had already become obsolete given Czechia's low unemployment rate and significant labour shortages in the automotive industry.

The government of Czechia approved the National Action Plan for clean mobility in 2015 following the requirements of Directive 2014/94/EU which obliged EU Member States to establish a national policy framework supporting the development of alternative fuels in transportation. The updated version of the National Action Plan was approved in Czechia in 2020. However, the government does not have any industrial policy that would help the automotive industry in its transition to the production of EVs beyond measures mandated by the EU.

The government decided not to subsidise individual BEV purchases, one of ten in the EU in 2021 (ACEA 2021a), with the exception of dropping the registration charges for BEVs emitting no more than 50g CO_2/km and the exemption from the annual highway use fee for BEVs of up to 3.5 tons. In 2019, the government had offered subsidies for the purchase of EVs by private firms but the total subsidy amounted to only 6 million euros (Prokeš and Charvát 2022). One of the reasons advanced by the government is that three-quarters of new cars are purchased by companies and only one-quarter by individual customers. Indeed, over 90 per cent of BEVs are bought by private companies. In other words, most individual consumers buy used cars.

In January 2022, however, the new government approved a subsidy of 40 million euros for the purchase of EVs by private firms and entrepreneurs, which should support the purchase of up to 4550 EVs. Providing a subsidy to private companies rather than individual consumers is thought to be a strategy to help to create a second-hand EV market through which EVs might more easily spread among individual consumers. The amount of the subsidy, which will be available up to the end of 2025, will be calculated from the difference between the price of an EV and an ICEV. Large companies (250 to 3000 employees) will receive 40 per cent of the difference, medium-sized

8. In August 2022, CATL announced a 7.34 billion euros investment on building a 100 GWh gigafactory in eastern Hungary (Reuters 2022).

ones 50 per cent and small businesses with fewer than 50 workers and individual entrepreneurs will receive 60 per cent. The average subsidy per car will be around 8000 euros. Finance will come from the EU as part of the subsidy announced in the National Recovery Plan.

Based on the EU directive, by 2025, one-third of all vehicles purchased by the public sector must be EVs and the Czech government will therefore provide subsidies to achieve this goal. Private companies will be able to receive the subsidy for the purchase of an EV until the end of 2025. The government also approved the subsidy of €12 million for 1500 charging stations (Prokeš and Charvát, 2022).

Overall, however, the government believes that, instead of subsidising car purchases, it is more efficient and environmentally-friendly to subsidise public transportation and encourage the public to use this instead of driving cars, thus lowering CO_2 emissions. Therefore, tens of billions of koruna will be spent on the purchase of electric buses, trains and other clean modes of public transport. A sum of 1.2 billion koruna (46 million euros) has been spent on the existing infrastructure (not only for electromobility but also on other alternative fuels infrastructure including hydrogen, for example), but an additional six billion koruna (230 million euros) is planned for the public infrastructure.

The combination of no government subsidies for the purchase of BEVs before 2022 despite their significantly higher prices than for ICEVs has resulted in a very low uptake of BEVs in Czechia. In 2021, there were only 8551 BEV cars registered in the country, of which 1195 were Teslas, 105 electric buses and 528 electric trucks (Ekovozy. cz 2021). With BEVs having a market share of 0.3 per cent in 2020, Czechia had one of the lowest rates in the EU. Interestingly, at 3.6 per cent, Czechia had the highest market share of vehicles in that year running on compressed natural gas (ACEA 2021b). In 2021, the share of EVs among newly registered cars increased to 1.28 per cent but was significantly lower than in Germany (13.6 per cent). That year, only 2646 new EVs were sold in Czechia, led by the Škoda Enyaq (832 units), followed by Hyundai (283) and Tesla (253). There were only 1500 charging stations in Czechia as of October 2021 (Prokeš and Charvát 2022), despite a government subsidy programme of 12 million euros.

At the same time, Czech politicians have been publicly complaining about the EU's CO_2 regulations for the automotive industry, including the 'Fit for 55' plan. Czech prime minister Andrej Babiš argued in 2021 'We have repeatedly said that the [EU's climate] goals must be set in a way not to harm our industry… It must be done reasonably, not based on ideology' (Prague Morning 2021). Political rhetoric blaming the EU for 'forcing' Czechia in the transition to electromobility was escalated by several minor political parties before the October 2021 parliamentary elections. Shortly after the new government was sworn in, new prime minister Petr Fiala declared, on 19 December 2021, that 'the proposal of the European Commission to ban the production and sales of [new] ICE cars after 2035 is unacceptable for the government of Czechia' (Aktuálně. cz 2021). The new minister of industry and trade added: 'I think it's nonsense to ban the sale of internal combustion engines. Technological advances may offer a better solution than harsh restrictions which may end up making everything more expensive' (Prokeš 2021c). It nevertheless came under the Czech EU presidency that agreement was reached by the European Parliament and the Council in October 2022 confirming the 100 per cent emissions reduction target for new cars and vans by 2035.

4.6 Job effects of the transition to electromobility in Czechia

It is difficult to estimate the job effects of the transition to the production of EVs in Czechia because of the complexity of the changes and the closely intertwined trends related to digitalisation and the automation of production (Industry 4.0). There will not necessarily be an overall trend but, instead, we might expect a complex mixture of job creation, job losses and job upgrading (Bauer et al. 2020).

As previously argued, Czechia is less specialised in the production of engines and gearboxes than Poland and Hungary (Pavlínek et al. 2009; Pavlínek 2017a). The Škoda Auto factory in Mladá Boleslav produces engines and its factory in Vrchlabí assembles automatic gearboxes, while Hyundai's Nošovice factory assembles gearboxes; it is likely that, in all these cases, assembly will be at least partially replaced by production for EVs. The Škoda Auto factory at Vrchlabí hopes to transition to the assembly of five million EV powertrains per year by 2031 (Charvát 2021), although a decision has not yet been made amidst intense inter-plant competition within VW Group.

Škoda Auto's plans to continue the production of ICEs after 2035 for non-EU markets means that it is unlikely that its engine factory will be closed in the next twenty years. However, the production of engines for the European market is already endangered if the Euro 7 emission standard is accepted and the company would have to stop producing 1.0 TSI engines, most likely after 2026. The company's unions have warned that this, along with any inability to secure the production of EV powertrains at Vrchlabí, could lead to the loss of up to 10 000 jobs. To avoid this worst case scenario, Škoda Auto has already secured the launch of the production of the 1.5 TSI engine at Mladá Boleslav (Váchal 2021). If it also succeeds in securing the production of EV powertrains at Vrchlabí, its job losses related to the transition are unlikely to be severe; redundancies related to the anticipated decrease in the production of engines are likely to be absorbed by the company and redundant workers retrained and reassigned, such as to the newly introduced production of MEB battery systems.

The future of employment at Škoda Auto and the job losses or gains related to the transition will indeed largely depend on corporate decisions by VW Group and will be the outcome of bargaining between Škoda Auto and VW Group over the allocation of future production. At the same time, this allocation will also depend on the outcome of cut-throat inter-plant competition between different VW factories in different countries as regards which of the locations with the lowest production costs (in particular the lowest wages, the most worker flexibility and the largest concessions provided to VW management), and also those with the strongest political power and influence at VW headquarters, are most likely to be successful in securing future production and investment.

Similarly, Hyundai Nošovice is gradually replacing the assembly of gearboxes with the assembly of car batteries. The assembly of gearboxes at its Gearbox factory II ended at the end of 2021 and will be replaced by the production of car batteries by Hyundai Mobis. The existing employees of Hyundai Nošovice will continue to work for Hyundai and the launch of the assembly of car batteries will create new jobs at Hyundai Mobis. Gearbox factory I will continue to assemble gearboxes for the needs of Hyundai Nošovice, Kia Slovakia and Hyundai's factory in Turkey (Lažanský 2021). However, production at Gearbox factory I will also be gradually phased out because Hyundai plans to stop selling ICEVs in Europe by 2035.

As previously mentioned, Toyota's Kolín factory has introduced the assembly of the Yaris, including the Yaris hybrid, resulting in the creation of 1600 new jobs (Dvořák 2021b). Thus the transition to the production of EVs has led to job creation rather than job loss.

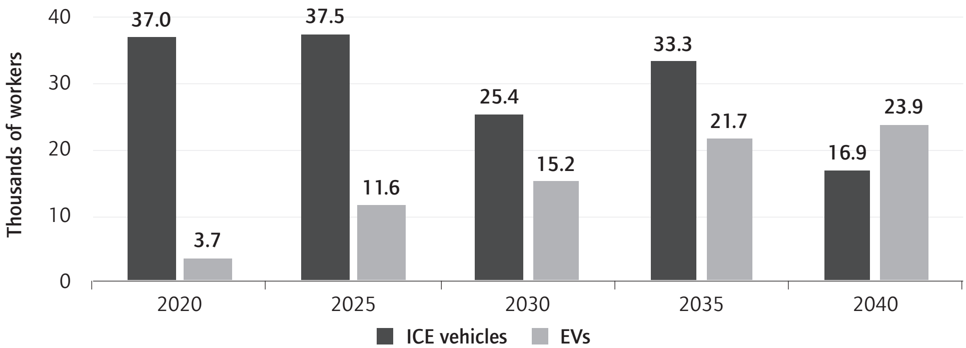
Overall, therefore, we should not expect significant job losses in the vehicle assembly sector (NACE 29.1 and 29.2) unless Škoda Auto experiences the worst case scenario, which seems unlikely at the moment. Rather, employment levels are likely to oscillate around current levels during the transition; or they may even slightly increase due to the potential increases in production fuelled by the lower production costs in Czechia than in western Europe, which has been the underlying reason for the growth in production and employment since the early 1990s (Pavlínek 2022, 2020). This reasoning is in line with the findings of the study conducted for Volkswagen by the Fraunhofer Institute for Organization and Industrial Engineering (Bauer et al. 2020), according to which we might expect that employment levels in assembly firms will be more affected by the trend towards digitalisation, increasing the efficiency of production and leading to labour savings, than by the transition to the production of EVs. Job reductions due to the transition are indeed likely to be moderate (Bauer et al. 2020). We might expect that assembly firms are most likely to address these by cutting the employment of temporary workers to protect the jobs of permanent workers.

Potential job losses will therefore be concentrated in the supplier sector and especially among suppliers of components to the fuel system, engine system, drivetrain and exhaust system that will become redundant in the EV powertrain. Overall, labour requirements are 70 per cent lower for the production of an EV powertrain compared to an ICE powertrain (Bauer et al. 2020).

According to the estimate of the European Association of Automotive Suppliers (CLEPA), about one-third of workers in the automotive supplier industry are employed in the production and development of ICE technology (CLEPA 2021). This would mean that up to 43 500 jobs (24.4 per cent) across the automotive industry in Czechia are potentially endangered as a result of the transition, although these potential job losses would be partially mitigated by job creation in battery production (Deloitte 2021).

More importantly, three additional trends are likely to mitigate potential job losses. Škoda Auto's plans to continue manufacturing ICEs beyond 2040 for markets in less developed countries will translate into the continuing production of components for these engines by suppliers in Czechia and abroad. Second, Czechia will continue to be an attractive location for the relocation of labour intensive production from western Europe because of its significantly lower wages and corporate taxation (Pavlínek 2020). Third, the production of ICEVs will continue longer in Czechia than in western Europe. All these factors will mitigate the short-term and medium-term negative employment effects in the supplier industry. CLEPA (2021) estimates the loss of 11 600 jobs in ICE technologies between 2020 and 2030 and an additional loss of 8500 jobs between 2030 and 2040, with a steep decline between 2035 and 2040, as shown in Figure 4. At the same time, however, 20 200 jobs are projected to be created in EV powertrain technologies between 2030 and 2040, as Figure 4 also shows.

Figure 4 **Projected employment in ICEV and EV powertrain technologies in Czechia, 2020-2040**



Source: Author based on data in CLEPA (2021).

Due to the decline in ICE powertrain employment, total powertrain employment is predicted to drop to 40 800 in 2040, approximately its 2020 level. However, job cuts and job creation will not take place in the same firms, which means that many suppliers of ICE components will face job reductions and might face closure, especially between 2035 and 2040.

5. The production of electric vehicles, plug-in hybrids and batteries in Slovakia

The overwhelming dependence on exports and on foreign capital by the automotive industry in Slovakia has two important implications in the course of the transition to the production of EVs. First, it will not be influenced by domestic demand and will be dictated by foreign demand for vehicles assembled in Slovakia. Second, it will strongly depend on the corporate strategies of foreign assembly firms and component suppliers, and the position of factories in Slovakia in their macro-regional and global production networks. Therefore, decisions about what will be produced in Slovakia, and when, will be made in corporate headquarters located abroad based on their global production, distribution and marketing strategies. Consequently, under the conditions of 'corporate capture' (Phelps 2000, 2008; Pavlínek 2016), the role of the government of Slovakia in facilitating the transition is limited to policies designed to create the most favourable national conditions for the investment and operation of foreign carmakers and component suppliers. These include large investment incentives offered to foreign multinationals and satisfying their needs in the areas of educational policy and labour force training.

All assembly factories in Slovakia have either started the assembly of electric vehicles or plan to do so. Progress to date (as at the end of 2021) is summarised below.

5.1 Volkswagen Slovakia

VW Slovakia had already begun to assemble purely electric mini BEVs – that is, the Volkswagen e-up! – in 2013. The Škoda CITIGOe iV and SEAT Mii electric, from the same new small family of VW minicars, began to be assembled in 2019. In 2020, VW Slovakia also produced five SUV models with plug-in hybrid engines for the VW, Porsche and Audi brands. In 2020, 42 275 BEVs and 28 875 PHEVs were assembled in the Bratislava factory complex. BEVs accounted for 13.7 per cent and PHEVs for 9.3 per cent of total vehicle production: a total of 23 per cent of vehicle output in 2020 (VW 2020, 2021).

5.2 Stellantis Slovakia

Stellantis Slovakia began to produce EVs in Trnava in 2019, with the launch of the new generation Peugeot 208 with an all-electric drive. In 2019, 7263 BEVs were made and output of the Peugeot e209 increased to 33 334 in 2020, representing 2 per cent of total factory output in 2019 and 10 per cent in 2020. The factory also assembles car batteries. Production started in 2019 with output of 10 000 batteries and increased to 35 922 in 2020 (Stellantis 2021).

5.3 Kia Slovakia

Kia Slovakia does not plan to assemble a BEV model before 2024. However, the gradual transformation to the production of electric vehicles began at the end of 2018 with the launch of the assembly of mild hybrids of the Kia Sportage, which accounted for 56 per cent of total output in Kia Slovakia in 2019. In 2020, the factory began to produce its first PHEVs, the Ceed Sportswagon and the Xceed (Žuffa 2020). In 2020, Kia Slovakia produced about 21 000 PHEVs, accounting for almost 8 per cent of total output. Mild hybrid versions of the Kia Sportage and Kia Ceed accounted for 11.9 per cent of all produced cars, or 31 916 units (Kia 2021). One of the reasons for the planned launch of the assembly of BEVs at Kia Slovakia are long delivery times (up to a year in 2019) of the Kia BEVs that are imported into Europe from South Korea (Malan 2019; Hampel 2019).

5.4 Jaguar Land Rover Slovakia

Although no information about the transition to the production of electric vehicles at JLR Slovakia has been released, the plug-in Land Rover Defender became available in September 2021. Since the Defender is made in Slovakia, we may assume that its plug-in version is being assembled in Slovakia as well (JLR 2021). A BEV Range Rover is not planned until 2024 (Randall 2021a).

5.5 Volvo Slovakia

In August 2022, Swedish car manufacturer Volvo announced its new 1.2 billion euros investment in eastern Slovakia for the production of electric vehicles. Construction will begin in 2023 and production lines will be installed the following year. Series production of electric vehicles should become actual in 2026, after which Volvo plans to produce 250 000 cars per year, creating 3300 direct jobs (Atena 2022).

5.6 Government policies and the transition to the production of electric vehicles in Slovakia

The government of Slovakia has traditionally been heavily involved in the development of the automotive industry (Pavlínek 2016). It should not therefore be a surprise that it has taken an active role in helping the industry transition to the production of electric vehicles. In 2015, the government approved its Strategy for the development of electromobility and its impact on the national economy, listing specific policies for the support of the transition in Slovakia. The proposed policies included the incorporation of electromobility in all relevant national strategies and policies; state subsidies for the sale of BEVs and PHEVs; government support for research, development and innovation; an information and education campaign; the construction of a national network of charging stations; and other measures (some 2015).

In April 2019, the Slovak government published a document on Measures to remove barriers to the sustainable development of the automotive industry in Slovakia, including the supply network. The Ministry of Economy established a working group in April 2019 to support the development of the battery industry in Slovakia and the Slovak Battery Alliance was established in June 2019 with a mission to foster the development of the battery industry in the country (SBaA 2021).

In contrast to Czechia, Slovakia has subsidised the purchase of EVs. In 2017 and 2018, the government supported electromobility with 5000 euros for the purchase of a BEV and 3000 euros for a plug-in hybrid (Petrík 2018). In November 2019, the Slovak parliament approved an amendment which made it possible to obtain a subsidy of up to 35 per cent of the price of a new environmentally friendly vehicle if its owner scrapped from the registry an ICEV at least 15 years old. An upper ceiling for vehicle price was set at 50 000 euros, which excluded luxury models from the subsidy. The actual subsidy was 8000 euros for the purchase of a BEV and 5000 euros for a plug-in hybrid.

However, the total annual subsidy allocated from the state budget was only five million euros, which translated into the purchase of only 625 BEVs per year (Petrík 2019). According to ACEA (2021a), there were no purchase subsidies offered in Slovakia in 2021; the government only lowered the registration fee for BEVs to a maximum charge of 33 euros, increased the depreciation of BEVs and PHEVs for two years and exempted BEVs from ownership taxes.

The 2015 Strategy elaborated two scenarios for the uptake of EVs in Slovakia. A standard scenario considered the sceptical public perception of electromobility and the conservative business environment, expecting a total of 10 000 BEVs and PHEVs in Slovakia by 2020. A more optimistic technology scenario assumed greater corporate involvement and a more positive public perception, resulting in 25 000 BEVs and PHEVs in Slovakia by that year (SMoE 2015). However, the uptake of EVs in Slovakia has been much slower: as of mid-2020, only 1582 BEVs and 1021 PHEVs had been registered in Slovakia. The main reason has been the significantly higher price of EVs compared to ICEVs despite the direct government subsidies.

The market share of BEVs was 0.5 per cent in 2020, slightly higher than in Czechia. But the total market share of alternatively powered cars, at 0.9 per cent in 2020, was lower than in Czechia (3.9 per cent) because of the lower market share of natural gas vehicles in Slovakia (ACEA 2021b). Despite the slower than expected growth of EVs in Slovakia, the Slovak Association for Electromobility expects up to 140 000 electric cars in Slovakia in 2030 (Lauková 2021) which, however, might constitute an overly optimistic scenario.

5.7 Efforts to secure a battery gigafactory in Slovakia

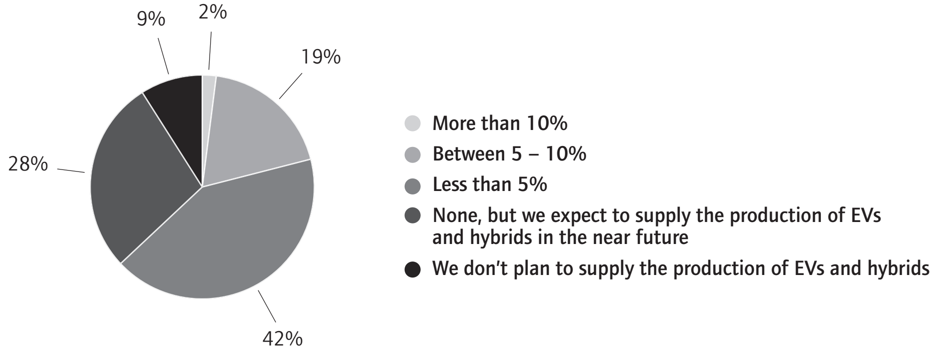
In 2018, InoBat, a Slovak startup that aimed to produce battery cells, was established to operate in the fields of electromobility, energy storage and hydrogen systems (Manthey 2019; Bolduc 2021). In 2019, InoBat partnered with the California-based energy technology company WDT, the owner of patented technology for car batteries, although most other European battery companies use technology licensed from South Korean and Chinese companies. Car battery tests have shown that, compared to the reference battery NMC 622, the InoBat battery is a quarter smaller and twice as electrically efficient (Lauková 2021). InoBat and WDT agreed to build a 100 million euro 100 MWh pilot battery line and R&D centre employing 150 R&D workers close to Trnava (at Voděrady). The Slovak government supported the project with a subsidy of five million euros in early 2020 (Domček 2020). The construction of the pilot factory, with a capacity of 260 000 batteries per year, was scheduled to start in the first half of 2020 and production to be launched at the end of 2021 (Manthey 2019), but the start of production was delayed until the end of 2022 or the beginning of 2023 (Lauková 2021).

In the future, InoBat plans to build a 10 GWh gigafactory (there have been conflicting reports about whether it would be at the same or in a different location) and produce up to 150 000 smart batteries per year. This was planned to be finished in 2024. InoBat has secured the support of a consortium of firms from Slovakia, Czechia, Hungary, Britain and the US on respect of construction. A smart battery should allow for a 20 per cent increase in range compared to the batteries currently in use, while InoBat says its battery reduces dependence on cobalt, one of the rare earth elements (Ehl 2020).

5.8 Job effects of the transition to electromobility in Slovakia

Based on a 2019 survey of 50 automotive component suppliers in Slovakia (PwC 2019), only 10 per cent of suppliers were concerned about the impact of the looming transition to the production of EVs and only 4 per cent about the effects of the digitalisation of production. Instead, the leading concern of the suppliers surveyed was the prospect of higher labour costs, confirming the importance of low labour costs for the establishment and continuation of production by foreign firms in Slovakia (Pavlínek 2020). The same survey concluded that 'the Slovak car industry is lagging behind' Germany and other countries of western Europe in the transition to electromobility (PwC 2019: 14). In 2019, 37 per cent of suppliers surveyed did not supply any components for the production of EVs and hybrids while for 42 per cent the share of supplies for EVs and hybrids was less than 5 per cent of total supplies, as Figure 5 shows.

Figure 5 **The share of total supplies for EVs and hybrids among 50 selected automotive industry suppliers in Slovakia, 2019**



Source: Author based on data in PwC (2019).

The survey results thus underscored the slower onset of the transition in Slovakia especially when compared to western Europe.

Overall, it is reasonable to expect similar job effects from the transition to those in Czechia. For example, Slovakia is also expected to produce ICEVs longer than in western Europe, not least in the light of VW Group's decision to transfer the ICE Passat from Germany to make space for the production of EVs in Germany. This will not only result in the investment of more than 400 million euros and job creation at VW Slovakia in Bratislava (VW 2021), it will also save jobs among those suppliers supplying engine components from Slovakia, at least in the medium term.

The automation of production in the Slovak automotive industry might well have more serious consequences in terms of job losses than the transition to electromobility. For instance, it has been estimated that automation may cause 30-40 per cent of jobs to disappear in the automotive industry (Filin 2021), which would translate into a loss of between 53 000 and 71 000 jobs.

We may expect a limited growth of automotive R&D jobs in Slovakia that may or may not be related to EVs. These R&D jobs will mainly be created by foreign firms attracted by low-cost R&D labour in Slovakia and by government investment incentives in R&D-related FDI. For example, in December 2021, the German supplier Shaeffler announced the construction of a 20 million euros R&D centre in Slovakia in the town of Kysuce that will focus on electromobility (Trend 2021). However, as in Czechia, foreign automotive firms face shortages of highly qualified R&D workers in Slovakia, which limits the development of R&D activities. Most foreign firms do not conduct any R&D activities in Slovakia. Similarly, domestic firms do not typically conduct any R&D and, if they do, it is typically small-scale and fragmented (Pavlínek 2018) although exceptions, such as the R&D centre for 150 workers that is under construction by InoBat, do exist. Consequently, relative to the overall size of the industry, Slovakia has recorded one of the lowest shares of business R&D expenditure in total production value and also of R&D personnel and researchers in the total number of persons employed. The automotive industry in Slovakia thus represents a typical example of truncated development (Pavlínek 2015a, 2017b) which is unlikely to be altered by the transition to the production of EVs.

Conclusion

The automotive industry has grown rapidly in Czechia and Slovakia since the 1990s due to the influx of profit-seeking foreign capital. As a result, both countries have large, mostly foreign-owned, export-oriented industries and rank among the largest vehicle producers in Europe. This rapid growth has, in both countries, created tens of thousands of jobs, increased exports and contributed to economic development. In the process, both Czechia and Slovakia have become strongly integrated in the periphery of the European macro-regional automotive industry production system. The level of growth has also increased the dependence of both economies on the industry, Slovakia being more dependent than Czechia. This puts Slovakia in a more vulnerable position during the transition to the production of EVs because of its more narrowly specialised industry, its greater dependence on foreign capital, its weaker domestic sector (Pavlínek 2018) and lower innovation and R&D capabilities relative to the size of its automotive industry.

The high degree of dependence on the automotive industry, combined with the relative position of the two countries in the European industry's integrated periphery, will have important implications for the future development of the industry in both countries. A successful transition to the production of EVs is therefore vital to the future economic development of each of them. The transition has already started as all foreign-owned assembly plants have introduced the production of electric vehicles and plan to expand production in both countries. At the same time, however, this transition will be slower than in western Europe because the integrated periphery will continue to produce ICEVs longer than factories in western Europe. The main reasons include lower production costs and modern, more efficient ICE factories than in western Europe having been built or modernised since the early 1990s. The lack of demand for BEVs and the continuing preference for ICEVs is a contributing factor to this trend.

This continuing production of ICEVs in Czechia and Slovakia, and a more gradual transition to the production of EVs, might lead to smaller or no job losses than in western Europe in the short and medium term. However, it might also put the industry in each country at a long-term disadvantage by developing weaker BEV competencies than in countries undergoing a more rapid transition. Ultimately, that would make Czechia and Slovakia less attractive for BEV manufacturing once the production of ICEVs has come to an end. This strategy is well demonstrated by Škoda Auto in Czechia, which plans to continue to produce ICEVs in the future alongside the production of EVs assembled on the same line, despite this type of mixed production being less efficient than having a fully dedicated assembly line to BEVs on the same platform.

A slower and more gradual transition in Czechia and Slovakia will have an effect on employment. We should not expect any drastic job losses in vehicle assembly as long as this continues to be profitable for carmakers in these two countries. Low wages combined with very large sunk costs in modern assembly factories, as well as the other continuing locational advantages of Czechia and Slovakia, such as proximity to western Europe, membership of the EU, political stability and a good quality transportation infrastructure, should ensure continuing production. At the same time, unexpected developments during economic crises or corporate restructurings can never be ruled out. Assembly firms are more likely to close their factories in foreign countries than in their home countries because of strong political pressures, union resistance and adverse publicity in their domestic markets (Revill 2008). For example, this makes VW assembly factories in Czechia and Slovakia more vulnerable to potential closure than ones in Germany.

Potential job losses related to the transition will be mainly concentrated in the supplier sector, particularly in the production of the powertrain. Analysis of the potential employment impacts in the supplier sector in Czechia revealed that total powertrain employment in 2040 will be approximately the same as its 2020 level since the decline in employment in ICE powertrains will be compensated by new jobs created in the production of EV powertrains. We might expect similar developments in Slovakia. As of now, labour shortages within the industry and rising wages are more pressing problems for most automotive firms than the prospects of job losses related to the transition, a result of the rapid growth of the automotive industry in both Czechia and Slovakia in the past three decades. This has undermined the competitiveness of labour intensive assembly operations in the components industry in particular, as well as the potential for the future growth of the automotive industries themselves.

The transition to the production of EVs is being driven by the corporate strategies of large foreign assembly firms in reaction to EU-wide environmental regulations of the amount of CO_2 released by the new car fleets of individual carmakers. The national governments in Czechia and Slovakia will play a secondary role in the transition. So far, both governments have pursued mostly 'wait and see' strategies and have not enacted any strong measures to support the transition at firm level. Their support has been limited to offering investment incentives to potential foreign investors, such as in the case of the planned gigafactory in Czechia.

Despite being transformative, the transition is unlikely to lead to dramatic changes in the development model of the automotive industry in these two countries and in the integrated periphery of the wider region. The basic features of the integrated periphery, highlighted by Pavlínek (2018, 2020) are likely to endure. There is little doubt that this transition will be directed and controlled by foreign multinationals and their profit-driven strategies in the context of their European and global operations. Given the extremely high degree of foreign ownership and control over the automotive industries in both countries, the transition will mostly be beyond the control of national governments which will be in weak positions to steer the development of the industries on their territories. This fundamental conclusion means that the truncated development of the automotive industry will continue in Czechia, Slovakia and in the rest of the integrated periphery, while the success of the transition to the production of EVs will depend on the corporate strategies of foreign multinationals being successful.

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Chapter 7
The Hungarian automobile industry: towards an understanding of the transition to electromobility

John Szabo, András Deák, Andrea Szalavetz and Gábor Túry

1. Introduction

The automotive industry has been a key driver of Hungary's economic growth and has led its integration into global value chains. Through this, the country has become a prominent element of the European industry by providing the manufacturing know-how and the low wages which have been key to ensuring the competitiveness of particularly German original equipment manufacturers (OEMs) such as Audi and Mercedes-Benz (Pavlínek 2017; Gerőcs and Pinkasz 2019). The industry's rise has continued on the back of a favourable business environment and ample foreign direct investment (FDI), contributing to economic growth, exports and job creation (Guzik et al. 2020; Jürgens and Krzywdzinski 2009; Pavlínek 2020). Over the years, manufacturers have streamlined their production of internal combustion engines (ICE) but the industry may be confronted with its biggest challenge yet: the shift to electric vehicles (EV). The Hungarian automotive industry and the jobs it provides are vulnerable to the long-term changes unfolding in the transportation sector, the impacts of which remain unclear. This study begins an exploration of how actors within the industry are assuming that these dynamics will unfold.

The jobs ensured by Hungarian OEMs and their suppliers are vulnerable to global competition. An immense portion of the industry's revenue hinges on the success of German firms (Braun et al. 2020) and their ability to compete in international EV markets. Chinese manufacturers have emerged as strong competitors in this space, which can have an adverse impact on the prospects of the Hungarian firms embedded in German value chains. To adapt, Hungary's automotive industry has to reposition itself from a focus on ICE vehicles (ICEVs) and component manufacturing to EVs. This transition may be slow, leaving actors with the time to adapt, but competition between countries and regions to establish themselves as industrial hubs has begun. There is a risk that jobs will be lost due to competition, automation and the low labour intensity required by EVs.

This study seeks to answer several questions related to the transition of the automotive industry, including what role Hungary will play in the changing European industry production chain. Will the transition from ICEV to EV production involve closing existing capacities and actors exiting the market? How great a threat is a downgrading of the industry due to technological and structural lock-ins? Can local stakeholders count on additional FDI inflows to create EV capacities? How will these developments and local investments be shaped by automation and digitalisation? While we address all these questions to some extent, it is their employment-related dimension that we tackle head-on in this study.

To answer these questions, we conducted a literature review, carried out desktop research and held interviews with experts, in addition to participating in three workshops focused on the matter. We convey our findings in this chapter, which continues with the research design in Section 2 and a broad introduction to the Hungarian automotive industry in Section 3. It then discusses the employment-related trends surfacing with the transition to EVs, before Section 5 looks at the impact of decarbonisation and automation. Section 6 explores the risks and opportunities embedded in the transition, while Section 7 provides an overview of the role that Asian battery manufacturers are playing in the country. Section 8 draws conclusions, based on which Section 9 offers policy recommendations.

2. Research design

Our research was driven by a curiosity about the emergent discourses pertaining to the automotive industry's transition and its impact on employment. This transition is still in its nascency, which limits our inquiry to what stakeholders think about the transition and how they are discussing it. We set out to sample the positions of key actors in the Hungarian industry who constitute six groups: (1) companies specialised in ICE-associated manufacturing (both OEMs and suppliers); (2) Hungary-based firms which are adapting to e-mobility; (3) new sectoral actors (e.g. battery manufacturers); (4) industry associations; (5) trade unions; and (6) the government. We were curious which narratives each identified as dominant regarding the transition's path and the issues this raises. To gather data for our discourse analysis (Fairclough 2013), we combined desktop research and interview-based qualitative data collection (Eisenhardt 1989). This began with a thorough literature review, but the early nature of the transition to EVs means that there is only a small amount of scholarly literature available on the matter. We complemented this with industry reports, policy papers and newspaper articles.

As a second step, we conducted our interviews. Our choice of stakeholders was based on the six groups listed above and which we identified from the literature review. We also sought input from researchers and consultants focused on the industry. To establish contact with experts affiliated with these stakeholders, we attended several industry workshops,[1] drew on our existing networks, identified potential candidates through online searches and relied on snowballing techniques (Tansey 2007). We conducted interviews with twenty-three experts, the full list of which is in Annex 1.[2] For the interviews we did not develop a research instrument or a list of specific questions but relied rather on our overarching themes to provide a basis for the questions we tailored to respondents. We inquired about three topics: (1) the expected impact of

1. These include a Portfolio-MAGE conference dedicated to developments in the automotive industry held in June 2021; a workshop organised by the Jedlik Ányos Hungarian e-mobility cluster in 2021; and an online conference organised by the Rosa-Luxemburg-Stiftung in November 2020 on the transformation of the automotive industry, with participants representing Hungarian trade unions.
2. Each interviewee was classified with a code, with specific contributions appearing in our text with that code in square brackets.

the transition to e-mobility on vehicle manufacturing in Hungary, with a particular emphasis on employment; (2) the Hungarian state's and companies' preparedness for the transition; and (3) what changes were emerging or anticipated in manufacturing plants. This approach provided us with the flexibility to engage in a discussion focused on the issues that interviewees themselves deemed to be the most prominent.

We then conducted a thematic analysis of the interview data, involving a process of transcribing, reading and re-reading, analysing and interpreting the insights obtained from our interviewees to identify the emerging themes (Neuendorf 2019). To capture the similarities and differences in individual narratives, we revisited our data multiple times, comparing and contrasting the perspectives of the individual experts we interviewed. Furthermore, we triangulated our interview input with other primary sources (e.g. policy papers) and secondary sources (Stake 1995).

3. The history and role of the automotive industry in Hungary

3.1 A brief history

The Hungarian automotive industry's roots date to the communist era, when output was dominated by bus (e.g. Ikarus) and heavy vehicle (e.g. Csepel and Rába) production. Vehicles were mainly sold in communist countries but exports reached a number of other countries as well, such as those in the middle east and Africa. After 1990, sales to eastern bloc markets fell sharply as the lack of development during the preceding decades had rendered many firms uncompetitive vis-à-vis western companies. Ikarus, for instance, quickly became indebted and, despite multiple changes in ownership, has still not been able to recover and launch the mass production of vehicles (Bódy 2015). Regime change also adversely affected Rába (Germuska and Honvári 2014), partly due to the loss of market share and outstanding debt. However, Rába managed to overcome the hardships and, following a successful reorganisation, became a leading axle manufacturer and a major automotive supplier. Rába's story underlines the general trend in which the Hungarian industry became predominantly limited to the production of components after the transition (Havas 2000; Stefanovics and Nagy 2021). This was partially a result of Hungarian OEMs' low competitiveness and the large investments made in component manufacturing during the 1990s.

The transition saw numerous suppliers go bust, but a handful were able to adapt and become pillars of Hungary's automotive industry. Rába Mór Kft., Videoton Holding, Kaloplastics, Ajkai Elektronikai Kft., Kunplaszt-Karsai Rt. and Pannonplast Group are amongst the core domestic suppliers that underpin the industry. In addition, leading European suppliers (e.g. Autoliv, Bosch, Continental, Schaeffler, Lear, ZF and Valeo) and overseas suppliers (e.g. Denso, Flex, Hanon, Nemak, Magna International and Visteon) all established a strong Hungarian presence in the 1990s. The industry has seen rapid growth since then, with large OEMs including Opel, Suzuki, Audi and Mercedes-Benz all launching operations. Production value more than doubled between 2005 and 2015 (see Table 1), driven by companies reinvesting earnings and shareholder loans (Báger 2015). Growth has slowed since 2015, primarily due to stagnant EU sales, but the industry's overall output remains substantial in a national, regional and European context.

The automotive industry accounts for 5 per cent of Hungarian GDP, 25 per cent of value added and 21 per cent of exports (ITM 2021). A total of 740 companies are involved in the manufacture of vehicles, directly and indirectly employing a total of 175 000 people in 2020 (ITM 2021). Like most countries in central and southern Europe, firms provide components for vehicles and undertake assembly-oriented activities (Lung 2007; Barta 2012; Gerőcs and Pinkasz 2019) – lower value added manufacturing is dominant (Pavlínek 2017). It is mostly the tier one suppliers that have invested in R&D and innovation activities, while this remains marginal in the case of OEMs (Audi is a notable exception). In 2017 and 2018, the Hungarian industry accounted for 10.22 per cent and 11.15 per cent of total R&D expenditures, respectively (Kuthi 2020).

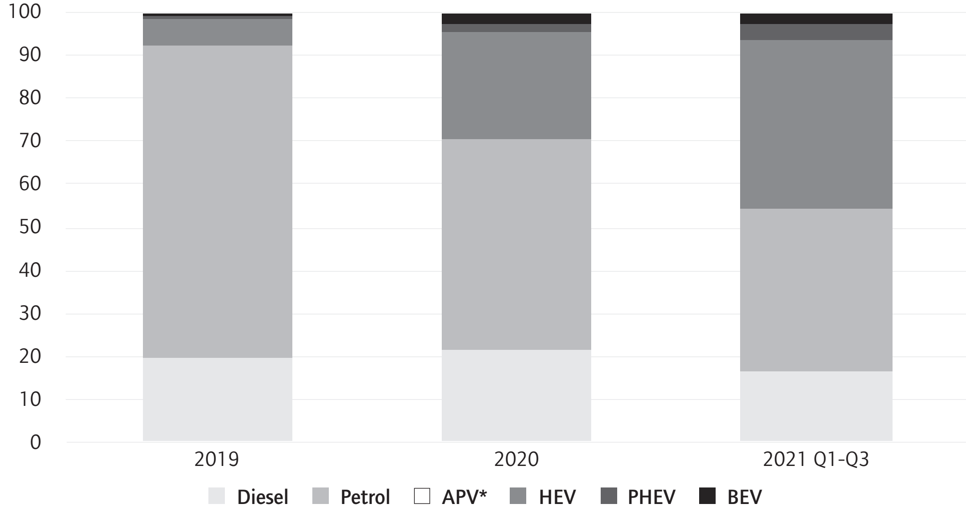
Table 1 **Main indicators of the Hungarian automotive industry**

Year	2005	2010	2015	2016	2017	2018
Enterprises (number)	507	485	494	487	491	497
Production value (million euros)	11 040	13 214	25 007	25 086	25 812	26 498
Persons employed (number)	63 236	65 153	88 555	92 958	97 703	101 908
Road vehicle assembly (number)	152 015	211 461	495 370	472 000	505 400	430 988

Source: Eurostat (2021).

Hungary's automotive output and its domestic market have generally developed largely independently of one another. The Hungarian market is small, with a population of under ten million, but also because the relatively low disposable income of households in comparison to their western European counterparts has historically impeded their ability to buy new vehicles. Instead, Hungarians tend to purchase used vehicles from western Europe [GOV6] (Szász 2020). There is nonetheless an openness from consumers to buying environmentally friendly cars (Csernátony 2021). The number of alternative propulsion vehicles as a percentage of all new vehicles sold showed a significant increase, from 8 per cent to 47 per cent, between 2019-21 (see Figure 1), led by a boom in the purchase of hybrid vehicles (from 6 per cent to 39 per cent of total sales). However, this remains a fraction of both the number of registered vehicles and the entire vehicle fleet. For example, relatively costly EVs essential for the decarbonisation of transportation are still beyond the reach of most people. This is reflected in EV penetration rates, which are 2.5 per cent in Hungary – despite doubling between 2019-20 – and which pale in contrast to Sweden (16.1 per cent), the Netherlands (12.7 per cent), Austria (12.7 per cent) and Germany (11.7 per cent).

Figure 1 **New car sales by powertrain in Hungary**



Source: ACEA (2021).

3.2 Production by location

There are four OEMs present in Hungary – Opel, Suzuki, Audi and Daimler (i.e. Mercedes-Benz) – and these are soon to be joined by a fifth, BMW (see Table 2).

Opel was the first to launch operations in Hungary when, in 1992, it began to assemble cars (the Opel Astra) and produce engines in Szentgotthárd, in western Hungary near the Hungarian-Austrian border. It ceased vehicle assembly in 1998 and shifted its focus to internal combustion engine and transmission production. After General Motors (GM) sold the plant to Peugeot (PSA) in 2017, the company further narrowed its focus to concentrate on internal combustion engines. The merger of Fiat Chrysler Automobiles and PSA led to the establishment of Stellantis which, as the owner of the Hungarian subsidiary, has announced that it will continue to produce ICE engines at the plant and invest in upgrading production lines and expanding output by 2023 (Szandányi 2021). Production has declined significantly in recent years and the plant is currently a long way from its maximum capacity of 350 000 engines per year; indeed, only 156 500 engines were produced in 2019 (see Table 2). The future of production in Hungary in the long term has been determined by PSA's announcement at the end of 2020 that it will no longer be investing in the development of internal combustion engines (The Detroit News 2020).

Japanese OEM Suzuki launched the assembly of cars in Esztergom (30 km north of Budapest) in 1992. The Hungarian factory is the company's first and only European production facility, where workers currently assemble ICE and mild hybrid models. The company has stated that its facility will continue to churn out hybrids in the medium term (five to ten years), but it is unclear when and how it may begin to undertake EV production (Autósajtó 2021) [IND2]. The plant's significance stems from its long-standing reliance on domestic companies which, in the early days, comprised 36 per cent of its suppliers – higher than in the case of other OEMs (Mészáros 2009; Urbán 2011). It has maintained this since, with 27 locally owned firms playing the role of Suzuki's tier one suppliers in 2019 (Gáspár et al. 2020).

Audi launched the production of internal combustion engines in Győr during 1993. The plant gradually became the wider Group's central powertrain supplier and the world's largest engine manufacturer, with a capacity of two million units per year. This scale underpinned its role as a key player within Volkswagen Group, even though it was initially launched as a pilot project in an empty Rába assembly hall. It began to assemble vehicles in 1998 with small series production; this grew, but total output remained below 60 000 vehicles until 2014 after which it increased to 165 000. In addition to engine production and vehicle assembly, the Győr facility also participates in developing engines and vehicles, as well as the tools used by other Audi plants. Audi Hungaria launched a shift to EV production in late 2018, reaching 5 per cent of total output in 2020 due to the slump induced by Covid-19 and the increase in EV sales (Portfolio 2021).

The latest OEM to launch Hungarian operations is Daimler in Kecskemét (southern Hungary), where the assembly of cars began in 2012. Mercedes-Benz established the facility to support its portfolio expansion, in which it increased its number of compact car models from two to five. The factory produces around 190 000 vehicles a year and began assembling battery electric models in October 2021.

Hungary's fifth car plant will manufacture BMWs in Debrecen (eastern Hungary). It was originally scheduled to start producing in 2022, but Covid-19 delayed the investment decision and the development of the project. Construction eventually began, however, in 2022 and the plant is poised to start production in 2025, three years later than originally planned (Németh 2021). The factory will have an output of 150 000 vehicles per year and will only assemble EVs.

Table 2 **OEM production in Hungary**

Number of vehicles/year		2015	2016	2017	2018	2019	2020
Audi	Cars	159 842	122 975	105 491	100 000	164 817	155 157
	ICE	2 022 520	1 926 638	1 965 165	1 954 301	1 968 742	1 661 599
	EV motors	0	0	0	9453	90 367	87 343
Mercedes-Benz	Cars	180 000	190 000	190 000	190 000	190 000	160 000
Opel	ICE	511 000	630 000	486 000	313 000	156 500	n.a.
Suzuki	Cars	185 000	211 266	170 000	175 000	177 718	112 475

Source: Authors' compilation based on companies' financial statements and corporate news.

3.3 Foreign direct investment in the automobile industry

Hungary has attracted significant investment supporting the expansion of its automotive industry since the 1990s. Alongside the four operating OEMs and the pending fifth, nearly 150 foreign suppliers have established operations in the country (Eurostat 2021). Their presence reflects the lure of the OEMs and the generally favourable business environment. The Hungarian National Bank's balance of payments statistics suggest that the 2020 stock of foreign capital investment in transport equipment was 9.2 billion euros (see Table 3). This is roughly a quarter of the total stock of foreign capital investment in Hungary's manufacturing sector, making the industry by far the largest recipient of investment. These levels have, however, declined in recent years. There have been no prominent plant closures, but output has declined recently, partly due to stagnant European demand and export opportunities outside Europe. The transition to electromobility is also a significant financial expense for companies (both OEMs and suppliers) [IND4]. Experts suggest that owners have gradually reduced their capital stock and that this may well have continued during the suspension of activities during the Covid-19 pandemic.

Table 3 **Foreign direct investment positions in vehicle production (NACE 29, 30: Vehicle and other transport equipment, billion euros)**

		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Hungary FDI flows	Transport equipment (NACE C29, 30)	0.2	-0.6	-0.2	-7.8	4.2	1.0	0.4	0.5	0.5	-2.4	0.2	0.6	0.1
Hungary inward stock of FDI	Transport equipment (NACE C29, 30)	4.6	4.0	3.4	-1.7	2.7	3.5	3.8	4.4	4.8	11.2	9.6	9.9	9.2
	Manufacturing sector (NACE C)	17.3	17.2	17.4	10.0	15.8	17.0	20.5	8.5	23.1	32.8	33.1	35.5	37.0
	Direct investment flows in Hungary	0.2	-0.6	-0.2	-7.8	4.2	1.0	0.4	0.5	0.5	-2.4	0.2	0.6	0.1
Czechia inward stock of FDI	Transport equipment (NACE C29)	…	…	…	…	…	…	9.7	8.7	8.3	7.7	9.9	10.0	n.a.
Slovakia inward stock of FDI	Transport equipment (NACE C29)	…	…	…	…	…	…	2.9	3.0	3.1	4.5	5.6	5.8	n.a.

Source: Authors' compilation based on CNB (2022); MNB (2021); and NBS (2022).

According to calculations by Pavlínek (2020), the index of foreign control in the Hungarian automotive industry was 94.9 in 2015. Antalóczy and Sass (2012) suggest that FDI data derived from current account statistics does not adequately reflect capital investment, meaning that we should treat the data made publicly available with caution. Moreover, information published by investors does not necessarily reflect total investment since it tends to include support received from government or municipal sources without noting their sums (g7.hu 2019; Portfolio 2021a).

It was greenfield investments that accounted for the growth in the 1990s, but the industry has generally made significant investments over the course of the past two decades as companies operating in the country have reinvested their profits (Ministry of National Economy 2013; Vápár 2013; Pavlínek 2020). For example, Audi invested more than 11.7 billion euros in Hungary up to 2020, expanding its scope of activities and developing the technologies it uses in its facilities (Audi Hungaria 2021). More recently, electromobility and investments in battery production have played a significant role in this investment boom. Suppliers have also undertaken significant greenfield and additional investments. Robert Bosch (2021), for instance, has invested a total of 200 million euros in its four production sites over the years. However, the overall picture shows significant capital withdrawal due to the consolidation of the industry. For instance, Audi Hungaria has reduced its share capital several times in recent years, transferring dividends to its parent company (mfor.hu 2021).

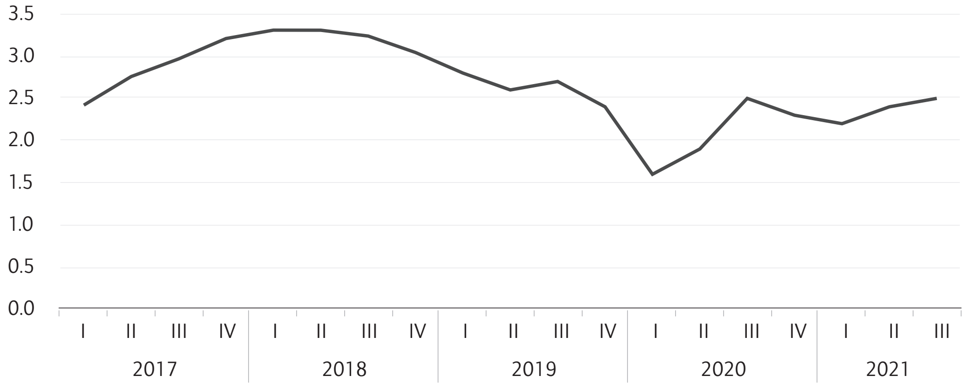
4. Developments in employment

As Section 3 (Table 1) discussed, employment in the Hungarian automotive industry has generally been on the rise in recent years: direct employment climbed from nearly 76 000 in 2010 to slightly below 161 000 by 2019; while indirect employment also increased, from 27 000 to 58 000, during the same period. Achieving such increases has been a strategic ambition of the governments that were in power during this period, all of them underscoring that their push to develop the industry was driven by its ability to provide good jobs [GOV2]. Government officials have repeatedly asserted that national economic development, quantified as GDP growth, rising amounts of local value added and a strengthened role for domestic suppliers, industrial and regional policy advances and even R&D development, is closely related to the jobs provided within the automotive industry. They have used this argument to justify the exorbitant subsidies provided to firms within the industry (Bucsky 2020). According to Vasvári et al. (2019: 1043), state subsidies amounted to 55 000 euros per job created by foreign-owned OEMs and suppliers in the period between 2004 and 2018, more than 70 per cent of all the subsidies allocated to foreign investors. In exchange for state support, companies used employment numbers as their 'bargaining chip' [GOV2]. Simply put, they claimed that more subsidies would lead to higher employment.

Historically, the common narrative and concern promulgated by experts is that the Hungarian automotive industry is only an assembly hall for OEMs (Gerőcs and Pinkasz 2019). In the 1990s and early 2000s, Hungary's competitive advantage hinged on a number of factors, the most prominent of which was a large, relatively skilled and cheap labour force, sustained as part of the Soviet legacy. The value added by Hungarian operations remained low as companies exploited the labour force while taking higher value adding processes abroad. OEMs and lower tier manufacturers sought relatively cheap labour in proximity to their main European markets (e.g. Germany) where they would also receive generous government support for their activities. The country welcomed these companies with open arms as it urgently needed an inflow of capital, while successive governments saw this as an opportunity to increase employment and boost the economy, ultimately underpinning their success in elections. The presence of jobs does offer a tangible outcome of governments' successful negotiations with corporations [GOV2] but this may be mostly rhetorical; jobs are a key testament to success but, in a context of the tightness in the labour market, noted by all interviewees, the need for them in the first place may have been something of a fiction.

Indeed, several indicators suggest that there are lingering labour shortage problems in Hungary. One is the decline in unemployment rates, which reached 3.7 per cent at the beginning of 2022. The figures are, however, disputed, since some calculations suggest that there are 180 000 active job seekers, although survey results indicate that this may be as high as 300 000 (Hornyák 2022). Meanwhile, the share of unfilled vacancies fluctuates around a relatively low level of 2.5 per cent (Figure 2). Employers are managing this situation mainly through overtime agreements, but a rising number are reporting labour shortages as an effective constraint on production – Astrov et al. (2021) suggest that, in 2019, this was close to 60 per cent in Hungary. To some extent, the increasing inflow of third country nationals has mitigated the problem. According to data published by the National Employment Service, 21 195 foreign citizens were employed in Hungary in 2020, 8.8 per cent of which were employed in manufacturing (NFSZ 2020). This number has quintupled in the past five years.

Figure 2 **Share of unfilled vacancies in manufacturing**



Source: KSH (2022).

The number of temporary agency workers is increasing [IND1; IND3; EXP1]. In 2019, the manufacturing sector employed 108 680 agency workers, 20 100 of whom were in the automotive industry (ITM 2020). This, in part, reflects the tightness of the market since workers have the ability to change jobs quickly and seek positions that offer the highest wages [IND3; UNI1]. High labour turnover also stems from the decline of regular employment providing job security and benefits. This became evident during the Covid-19 crisis when supply chain issues led OEMs and suppliers to lay workers off [UNI1], with those on temporary contracts the first to lose their jobs. While they were re-hired following the relaunch of production, it demonstrates the precarious position that many are in within the industry.

Thus, the quality of jobs is mixed at best: many relatively well-paying jobs are available but these are not necessarily accompanied by long-term job security and the benefits that were once available to employees. That being said, the tightness in the Hungarian labour market is shown in that OEMs establishing their operations were anticipating attracting labour from within their proximity (10-25 km), but this has now expanded substantially to multiple hundred kilometres, with workers frequently crossing borders [GOV5]. Thus, industrial areas are now seeking to compete to attract labour. In theory, this provides workers with leverage but there is a lack of organisation and mobilisation to expand the reach of unions beyond the few that are active.

The automotive industry has nonetheless been of appeal to workers since it offers relatively high wages both nationally and, especially, in the Hungarian regions where they operate [GOV5; UNI1]. Higher pay is still a key lure but Hungary's weaker labour laws undermine job quality. Most recently, Parliament's ratification of the so-called 'Slave Law' increased the amount of overtime employers can demand from 250 hours to 400, while compensation can be delayed for up to three years (hvg.hu 2019). This further move in the 'race to the bottom' may increase Hungary's competitiveness in the broader region but it also curtails the power and well-being of employees (Artner 2020). Their self-determination is further impeded by the limited influence of workers' unions. Unionisation in the industry is relatively high in a national context, but their historical role does not reflect deep roots comparable to the German system, for instance [UNI1]. Unions were set up afresh after the communist era and sought to mimic the German model, but with little regard to the socio-cultural context. Their influence continues to be quite limited, even though they have been very successful in organising strikes and protests on a handful of occasions [EXP1].

The trajectory of employment has not yet led stakeholders to sound alarm bells. However, the tightness of labour supply may worsen in the short term, not least as BMW moves towards launching operations at its Debrecen factory. The manufacture of electric vehicles may generally be less labour intensive than their ICE counterparts (FTI 2018), but the wider dimensions and full implications of this transition have yet to be explored in Hungary. Most interviewees were not particularly worried about job losses in the short to medium term, although their reasons varied [IND8; GOV1]. One key factor underlined by most interviewees is their expectation that the transition will be gradual, providing all actors with ample time to respond, although some strongly dispute this [EXP2]. While the European Commission's 'Fit for 55' targets will hasten the transition to EVs, it still leaves five to ten years for actors to adjust. Corporate stakeholders did not expect further large-scale lay-offs related to ICE technologies since large portions of manufacturing processes have already been automated [IND2]. Most OEMs have concluded their automation programmes and do not anticipate further lay-offs [IND3].

A number of factories are undertaking activities such as the assembly of vehicles that would not require a smaller labour force as the EV transition escalates. Vehicle assembly does play a prominent role in Suzuki and Mercedes-Benz and, to some extent, Audi.

While the latter assembled a record 171 015 vehicles in 2021 (Audi Hungaria 2022), the relatively large weight of ICE manufacturing in its portfolio makes it susceptible to larger changes that may involve lower labour demand. Its factory in Győr produced 1 620 767 engines that same year, but the number of electric powertrains was a mere 96 976 – just 6 per cent of the total. The firm anticipates gradually increasing the role of EV production in line with its headquarters' strategy, the most recent of which was '*Vorsprung 2030*'. Based on this and the additional guidelines provided by Audi, the Hungarian subsidiary is developing five-year product, financial and manufacturing plans [IND3]. Interviewees suggest that the competitiveness, geographical location and capacities of the plant position it well in adapting to the transition, which it has signalled through further investments in its tooling plant and other technical developments (Audi Hungaria 2022).

Regarding suppliers, our interviewees contend that their firms are specialised in producing components that can be integrated into both ICEVs and EVs [IND6; EXP2]. Consequently, they suggest that the transition will not jeopardise their employees. In contrast, suppliers specialised in manufacturing parts of ICE drivetrains, such as exhaust systems, will face increased competition and significant reduction in demand [EXP2].

Job losses may not occur *en masse*, but the labour market will be restructured during the transition. There are two important dynamics here. The first is that German automotive manufacturers are committed to state mandates to maintain their employment numbers [IND3]. They can do this either by increasing output or by 'deepening production'. The feasibility of the former is questionable. Not only is competition intensifying with other OEMs, but there is a generally shifting relationship to vehicle ownership, car sharing becoming increasingly popular amongst younger generations [GOV5], and this may impede higher sales. Both limit the growth of German manufacturers. Thus, alternatively, to maintain their labour force, these companies must seek to deepen production which entails them expanding in-house activities. This can lead OEMs to acquire suppliers and integrate their activities which, through streamlining, could lead to lay-offs. In this way, OEMs would be able to maintain employment figures but this is bound to have an adverse effect on SMEs and employment throughout the value chain.

Secondly, interviewees noted that the labour force is migrating from one part of the value chain to another. The skilled workforce currently focused on R&D may be forced to take jobs in manufacturing and in servicing and maintenance during the next 20-30 years [GOV5; GOV6]. Again, the question is what sort of jobs the industry will be able to provide, but interviewees suggested that those engineers working on R&D projects could be reskilled to take relatively good jobs (e.g. in manufacturing, automation or as project engineers) in the manufacture of EVs. The shift will be a step down for many, but it would still provide relatively high living standards for skilled professionals. Instead of mechanical engineering-type tasks, they may be assigned the design of automation or of assembly lines, the ramping up of production or the design of testing activities. Demand for some traditional blue collar activities, such as machining and drilling, is also bound to be reduced. The shift may also force those working lower down the value chain to change their jobs.

A further factor in employment hinges on the activity of trade unions. These are currently mostly occupied with managing day-to-day activities and have little surplus capacity to tackle the long term issues presented by the transition [UNI1; UNI2]. As the labour market is restructured by the prevailing dynamics, workers are set to be further atomised and splinters between generations and occupations are already surfacing. This is not to say that unions are not trying to respond (e.g. by launching re-training programmes) [UNI2], but their role is limited and this is poised to weaken further in forthcoming years. However, there is a counterforce: the rising importance and scarcity of electricians and electricity-related skills. While the emergence of these competencies increasingly fragments existing labour relations, these highly skilled workers have the opportunity and have shown the initiative to organise [GOV5]. This can be a crucial point of departure that reverses the negative implications of structural changes in automotive industry employment.

These will, however, face an uphill battle as Asian firms (e.g. Suzuki) and newly established battery manufacturers have been especially attentive to, and dismissive of, unionisation (Papp 2019).

5. Possible effects of decarbonisation and digitalisation

5.1 Technology

Decarbonisation and the adoption of new technologies will considerably change the automotive industry, but how this will materialise is still the object of speculation. Some of our interviewees are questioning which technology will emerge as the leader out of the technological alternatives available [IND1; IND8; UNI1]. Nonetheless, there is broader consensus that EVs will become dominant [NGO1; NGO2; IND1; IND3], even if they may be complemented with other technologies. This contingency causes concerns for stakeholders since they do not know where to invest. Irrespective of the outcome, multiple interviewees noted that the wider industry is aware that current investment patterns will not be sufficient to maintain the competitiveness of the value chains already in place [GOV2; IND11; UNI1]. However, they did not have answers as to what form government policy should take since the technological matrix has not been set [GOV5]. What is more, to what extent the government should be involved in choosing favourites or allowing the market ultimately to decide remains unclear [GOV2]. The government of Hungary has continued to provide some support for ICEVs, but it has begun to place greater emphasis on supporting the move to EV manufacturing [IND10]. This has materialised in its support for BMW's EV ambitions and the shift in Audi's plant.

A key pillar of the government's strategy for decarbonisation is its involvement with improving R&D capabilities within the country [GOV5]. It approaches R&D as a cost-efficient point at which to intervene in the automotive value chain, allowing local actors to develop technologies, increase value added and develop facilities that support output in Hungary. This was also confirmed by one interviewee [IND4], who commented that increasing value added was also key for the competitiveness and survival of suppliers. This would also enhance the resilience of the domestic sector regarding future changes [GOV6].

A flagship project of the government in this area is the ZalaZONE Test Track and auxiliary facilities which can offer a platform to develop a host of technologies related to autonomous driving capabilities [IND10]. Its appeal lies in the limited availability of such tracks and the low price point at which it can be used, leading it to be fully booked [GOV5; IND9]. Simultaneously, it should be noted that the value of the track has been questioned by many, given high construction costs and concerns over corruption. According to the government's vision, the track and the research facilities in its vicinity will attract further R&D for which the government has provided ample funding [GOV6]. It will then become a bridge to European automotive development [EXP3], which would have a spillover effect, boosting manufacturing and other services.

5.2 Skills

By localising R&D capabilities, the government is fostering the development of domestic manufacturing and encouraging improvements in the education system. The latter is urgently needed, with government expectations suggesting that the 3000 engineers currently employed in automotive R&D will double in forthcoming years [GOV5]. As it stands, formal education, based on the network of state universities, colleges and other institutions, cannot meet the demand posed by the industry as its curricula frequently lags behind the rapid technological progress made by the industry. There is already a strong concerted effort between government and industry to establish education programmes that cater to rising needs, which – combined with the still relatively inexpensive workforce – would offer a key competitive advantage for Hungary in the maintenance or even advancement of its position in European value chains [GOV6; UNI1]. The issue is that it takes two to three years to develop engineering education programmes while large parts have already become obsolete in the interim. This has become an especially pervasive problem with regard to newly established and quickly growing sectors, such as battery production, and may pose a general impediment to the domestic sector's ability to adapt to a changing environment [GOV5; IND5].

Interviewees were clear that new competencies needed to be added to the skillsets of employees, considering the skill requirements posed by automation, digitalisation and the transition to e-mobility. Digitalisation and the increasing automation of main production tasks is considered a more important driver of change in the content of work than e-mobility [IND1]. In the case of the latter, the only issue raised by interviewees was the need for a new set of safety measures to be learned and included in a variety of tasks [UNI2; GOV6)]. In contrast, interviewees claimed strongly that workers' ability to perform tasks alongside robots needs to be improved. Given the prohibitively high rate of voluntary departures and labour turnover, even novice employees are found to be familiar with working alongside robots that complete tasks such as line loading, machine tending and in-plant logistics. However, there is a scarcity of employees with the ability to programme and operate these robots. In a similar vein, the ability correctly to interpret feedback from the machines (when controlling automated systems) is paramount. A knowledge of how to keep operations running requires a more advanced skill set from the labour force.

The changes in employment are, however, unfolding slowly. New products – be that a vehicle or a part or component – introduced by manufacturers requires employees to be trained since these all involve incremental adjustments in tools and ways of working or, on occasion, they may lead to even greater changes. Consequently, both operators and employees are accustomed to constant shifts in the way they work, a flexibility which has become a key asset [GOV1].

Complementing and adding some nuance to the average rosy picture of the accumulation of new digital skills and the upgrading of the content and quality of work, one interviewee [UNI2] described an adverse scenario involving an automation-induced process of deskilling. In this scenario, the core processes are robotised and, in consequence, fewer skilled operators are needed. For instance, in the case of welding operations, workers would not be engaged in operational interventions using special purpose equipment to carry out given processes. Instead of welding, workers would perform simple auxiliary tasks alongside welding robots, including monitoring them. This grim picture was, however, not supported by other interviewees [IND2; IND3]; what is more, interviewees suggested that automation may have to be accelerated to overcome labour shortages: a contrasting view to automation leading to unemployment or the materialisation of dystopian outcomes.

6. Additional risks and opportunities

A key risk is whether foreign OEMs will be able to maintain their market dominance [GOV2; GOV5; IND1]. This depends on the European – and primarily the German – automotive industry's ability to maintain its competitive advantage as it faces fierce competition with the rise of e-mobility [IND10]. Without government intervention and an orchestrated industrial policy, the transition may have outcomes that are worse than expected and this may lead to a substantial decline in the labour force employed within the industry. This risk is thus mostly linked to broad global trends and the ability of German OEMs to outcompete other companies. It also closely links to manufacturers diversifying between technologies and various transportation segments [GOV5]. Difficulties among OEMs would send shockwaves through the value chain and endanger lower tier suppliers, especially locally owned, smaller companies that already have difficulties in adapting to a changing context. These provide jobs and growth, but this may decline without sufficient support to adapt to new needs. Successful government policies boosting the competitiveness of small and medium-sized enterprises will be crucial in forthcoming years to maintain the health of the overall industry and regional economies [GOV3; GOV4].

The transition will also require new skills and competencies in effectively all segments of the supply chain, amplifying the need for innovative, up-to-date training programmes without which the transition may wreak havoc. Skilled labour in existing automotive and new facilities (e.g. battery production) are already in short supply, but there is generally a lack of highly trained electricians and technicians competent in processes related to EV development, manufacturing and maintenance. The government is aware of the matter and has systematically attempted to address the issue by upgrading university research facilities as well as updating education and training programmes [GOV5; GOV6]. A recent testament to this is its focus on the ZalaZONE project, but this is only a start and all respondents underlined that the deficit in skilled labour is likely to be a sustained one.

A recurring pattern in our interviews is employers highlighting that the transition will require new skills [EXP2; GOV1]. Instead of speaking about specific skills, such as arranging wires, mounting bearings or operating specific shopfloor machinery, employers emphasised that future workers need to possess adaptability skills (e.g. to be able to adapt to new technologies and/or to changing job assignments); collaboration and self-management skills (to be able to work in teams when the composition changes from time to time); and problem-solving skills [IND8; GOV1]. This will be even more important if automation-heavy production expands. One interviewee noted that:

> Employers are looking for different competences than before. Previously, when we asked what kind of new employees they were looking for, companies pointed to specific occupations, informing us that they needed welders, mechatronics technicians, forging machine operators and so forth. Nowadays, companies rather ask for skills and competences such as flexibility, openness to learning new skills, basic IT and digital skills and problem-solving skills. You can imagine how difficult it is to decide whether a job seeker possesses these competences or not. [GOV1]

The ability of the labour force to adapt is certainly one of the largest risks that Hungary's automotive industry faces.

7. Foreign investments by Asian manufacturers in Europe with a focus on new technologies

Historically, investors channelled funds into the development of ICEV but this has shifted to electromobility since the mid-2010s. As discussed above, traditional manufacturing plants and component manufacturers geared towards ICEVs have begun to expand their portfolio to EVs as well. Investments that are solely targeted at EV output have accompanied this. One of the world's leading electric vehicle manufacturers, the Chinese firm BYD, has set up a plant in Komárom to produce electric buses. Its operations launched in 2017 and output was envisaged as growing to one thousand buses per year by 2022 (Patthy 2020). Meanwhile, Hungarian-owned Ikarus Járműtechnika and Chinese railway vehicle manufacturer CRRC established a joint venture in 2018 to assemble electric buses. This will take place at Ikarus's Székesfehérvár site, repurposing the assembly hall that once churned out ICE buses, but the timeline for the launch of operations remains unclear. In addition to producing and assembling EVs, Asian investors have also developed production capacities to supply the automotive industry. This entails product development in their existing plants (e.g. TDK Hungary Components, Zoltek) and greenfield investments as well (e.g. Chevron Auto).

Asian investors have already channelled significant amounts into battery production as well (see Table 4), but plans suggest that further expansion will continue (Schade et al. 2022). This was a common theme of our interviews in which all interviewees addressed the recent emergence and rapid expansion of Asian battery production capacities in Hungary. A total of 5.29 billion euros has been directed into battery production since 2016, creating 14 000 jobs (ITM 2021), while production capacity has risen to 20 GWh per year – compared with the EU's 35 GWh (Major 2021). Battery production has also become a leading point on the government's industrial policy agenda through which it has lent support predominantly to Asian firms. Hungary has attracted substantial investment from Chinese, Japanese and South Korean companies, with others also considering investing in the country [GOV6]. Hungary's popularity is at the intersection of a number of factors, including government policy, the country's pre-existing role in European automotive supply chains, relatively inexpensive labour costs, a favourable corporate tax regime and low energy prices (Schade et al. 2022).

Table 4 **EV battery manufacturers in Hungary**

Company	Country	Activity	Location	Investment (bn forint)*	Year of establishment
Tier one / primary producers					
SK Innovation	South Korea	Battery factory	Komárom	689	2018
			Iváncsa	681	2021
Samsung SDI	South Korea	Battery factory	Göd	540	2017
GS Yuasa	Japan	Battery factory	Miskolc	14.8	2019
Inzi Controls	South Korea	Battery parts	Komárom	9	2020
Tier two and three suppliers					
Semcorp	China	Battery separator foil	Debrecen	66	2021
Solus Advances Materials/Doosan	South Korea	Copper foil factory	Tatabánya/Környe	106	2020
Toray/Zoltek	Japan	Battery separator foil	Nyergesújfalu	127.5	1995
Soulbrain	South Korea	Electrolyte	Tatabánya	n.a.	2021
Mektec/enmech	Japan	Battery parts	Pécel	n.a.	2020
Sangsin EDP	South Korea	Battery frames	Jászberény	10.5	2018
KDL Shenzhen Kedali Industry	China	Battery parts	Gödöllő	14.1	2021
Iljin Materials	South Korea	Copper foil factory	Gödöllő	3.8	2021
Dongwha	South Korea	Electrolyte and recycling	Sóskút	11	2021
Shinheung Sec	South Korea	Battery frames	Monor	8	2019
SungEel Hitech	South Korea	Battery recycling	Szigetszentmiklós	1.8	2017
Bumchun Precision	South Korea	Aluminium battery terminals for electric vehicles	Salgótarján	13.3	2018
Lotte Aluminium	South Korea	Aluminium anode foils	Tatabánya	44	2019

* Average forint:euro exchange rate for 2021 was 358.5:1.
Source: Authors' compilation based on ITM (2021).

The rapidly expanding battery production facilities cater to the rising demand of automotive OEMs and others. So far, these activities have been led by east Asian companies that have established labour intensive, but low value added, production sites. For example, SK Innovation's gigafactory in Iváncsa, the largest greenfield project in Hungary to date, enables the production of batteries for approximately half a million EVs a year (HIPA 2021). Hungary ranks 16th on the global lithium-ion battery supply chain ranking by BloombergNEF (2021), behind 14th placed Poland and 15th Czechia, but ahead of Slovakia, which highlights its prominent role in the sector. This is further underscored when considering its expected growth.

These production capacities are, however, targeted at foreign markets, indicating that domestic value chains have not yet shifted their operations to absorb battery output, unlike in Czechia, for instance.

Battery factories have created a significant number of new jobs. During one interview, a human resources executive revealed that, although the battery manufacturing process is highly automated, employment at the local facility is high – more than 1100 employees in 2020 [IND5]. Most employees are operating production line machines. This requires a certain level of technical knowledge – a basic understanding of the machine as well as expertise in navigating a menu that contains information and instructions – but most of their specific skills can be learned on the job. According to the manager interviewed, this expertise is similar to that of mastering the navigation of the menu of a smartphone and typically requires two months of learning by doing.

However, concerns over working conditions have been raised. While the level of pay is acceptable, they have been referred to as bad jobs [UNI1]. There are also concerns about working with hazardous or toxic materials, suggested by interviewees [NGO1; NGO2; UNI1; EXP1] but also publicly reported (Partizán 2020), even if those working within the sector question or refute such claims [IND5; IND11]. Such factories have also had a negative impact on the environment, as well as on those who live near the facilities, exposing them to pollutants and noise pollution, but they have been able to take little action as the government's support and the power of the companies involved has left them rather helpless (Partizán 2020).

8. Conclusion

Drawing on the experiences of Hungarian automotive stakeholders, this chapter investigated whether the disruptive forces transforming the industry are producing a structural lock-in in factory economies that are highly specialised in ICE-specific manufacturing activities. More specifically, we explored the first signs of local adaptive transformation and collected and analysed experts' and stakeholders' views of the medium term impacts of the transition of production to electromobility and digital. Our point of departure was that the structural transformation of the Hungarian automotive industry is well on its way. The country has a long-standing tradition in manufacturing vehicles which, until now, have been propelled by internal combustion engines. As the EU-driven response to the climate crisis unfolds and global demand for internal combustion engines withers away, the Hungarian industry has also begun to adjust and shift operations to produce electric vehicles.

For now, there is a tightness in the labour market and demand for labour is robust, but the Covid-19 shock and the disruption in the supply of chips have highlighted the precarious position that many workers are in. Those on short-term contracts or employed by companies lower in the value chain are susceptible to disruptions as they are the most vulnerable. The government has supported job creation related to EVs to preserve the industry and adapt it to a decarbonised world, so it has been able to create jobs although these have not always been good jobs. Further automation and the expansion of EV production is set to alter the structure of the labour force, shifting many downstream and forcing them to retrain. This is a huge task that needs ample government support and long-term planning, which is mostly absent among the actors.

Our results do not confirm that the country's industry faces a structural lock-in; at least, not in the short or medium run. They do show a case that we refer to as a lock-in *in a dependent model of capitalism* (Farkas 2011; Myant 2018; Nölke and Vliegenhart 2009). Since both the transition to EVs and the implementation of advanced manufacturing technologies elicit significant capital-deepening, while engendering industry concentration at all stages of the automotive value chain, a dependent factory economy like Hungary will become even more exposed to the strategic decisions of global companies along the chain. Specifically, this regards the decision of whether the existing investors remain committed to locating capital and knowledge intensive activities in a host country that has so far been competing on the basis of low labour costs.

Hungary seems to be in a good position as the output of firms is adapting to changing needs and it has been able to lure both European and Asian companies to establish operations essential to EV production. This may even enhance the tightness in the labour market, but this is unlikely to last long. If government policies are not regularly rethought and adjusted along strategic lines momentum may be lost. Moreover, policymakers needs to consider carefully the quality of the jobs that it maintains since this will be crucial in sustaining the wellbeing of citizens and their support for the transition.

9. Policy recommendations

Our findings suggest that the imperative of aligning policy instruments in a synergistic way should be a focal consideration pursued by policymakers when developing their agenda. The importance of consistency and coherence cannot be overstated as haphazard interventions without long term, aligned goals will inhibit the Hungarian automotive industry's competitiveness and, with it, the good jobs that it currently sustains. Currently, policies embody conspicuous contradictions. Some support is directed to upgrading the capacities of incumbents and the creation of better jobs. With this, they are fostering the industry's adaptation to high value added activities within EV supply chains. Programmes that support firms' digitalisation and the implementation of advanced manufacturing solutions will increase investors' commitment to developing the EV-specific production activities of their Hungarian subsidiaries. This is something which is also deeply reliant on supportive education policies being developed in cooperation between the state and the industry.

In contrast, there has been an overwhelming government push to introduce labour market policy instruments which attract FDI, but are characterised by 'race-to-the-bottom' behaviour, suppressing wages while reducing the stability of jobs, offering subsidies from public purses and curtailing environmental standards. Examples include the so-called 'Slave Law' deregulating overtime work and the lenience of the government towards specific companies owned by Asian investors who recurrently repress labour unions and ignore employees' rights to decent working conditions (Artner 2020). The issue with this behaviour is that it hinders the creation of quality jobs. In the quest for low labour costs, the upgrading of vocational and higher education is being neglected, exacerbating the shortage of skilled labour. Consequently, investors are not motivated to locate high value added activities to local production sites – including EV-specific production that requires a skilled workforce in all business functions (not only IT specialists and engineers but also technicians with domain-specific and programming skills and operators with at least intermediate technical competencies).

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Annex 1
Interviewees

No.	Code	Name	Position	Actor type
1	EXP1	Anonymous	Researcher	Research institute
2	EXP2	Anonymous	Managing director	Consultancy
3	NGO1	Anonymous	President	NGO
4	NGO2	Anonymous	Expert	NGO
5	IND1	Anonymous	Executive	Industry association
6	IND2	Anonymous	Executive	OEM
7	IND3	Anonymous	Executive	OEM
8	IND4	Anonymous	Head of finance and accounting	Tier one supplier
9	IND5	Anonymous	HR officer	Battery manufacturer
10	IND6	Anonymous	Deputy managing director and marketing manager	Tier two supplier
11	IND7	Levente Reizer	E-mobility project manager	Nissan
12	IND8	Szabolcs Karaszek	Director of human resources	BorgWarner Oroszlány (Tier one supplier)
13	IND9	Anonymous	Project manager	Test track operator
14	IND10	Anonymous	Executive director	Tier two supplier
15	IND11	Anonymous	President	Electromobility association
16	UNI1	Anonymous	Executive	Trade union
17	UNI2	Zoltán László	Vice-president of union federation	Vasas trade union
18	GOV1	Anonymous	Head of employment office	Local government
19	GOV2	Anonymous	Former deputy secretary	Ministry of Innovation and Technology
20	GOV3	Anonymous	Managing director	Urban development organisation
21	GOV4	Anonymous	Project manager	Urban development organisation
22	GOV5	Anonymous	President	Innovation-related government organisation
23	GOV6	Anonymous	Senior advisor	Ministry of Innovation and Technology

Chapter 8
Poland and Romania: a transition delayed?

Philippe Darteyre and Stefan Guga

Introduction

The accelerating transition to electric vehicles and the rapid shift to a new mobility paradigm imply major challenges for the European automotive industry and its supply chain. This massive and unprecedented disruption raises legitimate questions about the future role of central and east European (CEE) countries in the European automotive value chain as fast-track electrification is pushing manufacturers to rethink their industrial and commercial strategies on their way to carbon neutrality.

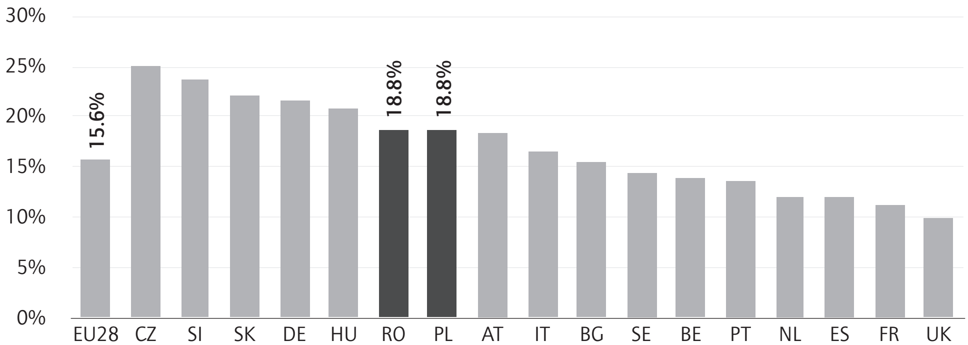
This chapter looks at the peculiarities of the powertrain transition in the automotive industries and markets of Poland and Romania, two CEE countries in which this industry has played a major role in socioeconomic development in recent decades. Historically, Poland has been an important low-cost location for internal combustion engine (ICE) powertrain components; while Romania is home to two highly successful plants specialised in low-cost vehicles. Specific to the CEE region, the trajectory of automotive sites in Poland and Romania strongly depends on strategic decisions made in companies' headquarters located outside the region. The question today is whether these two countries will join the technological transformation early on, or rather be kept as low-cost manufacturing bases for relatively low-end ICE technologies. The answer has deep implications for employment prospects in both countries.

In Section 1, we present the main features of the Polish and Romanian automotive industries. We also describe the structuring factors that have sustained their development over the years, in particular the massive investment inflows from foreign companies attracted by low labour costs and generous state incentives. We also discuss the unusually strong weight of suppliers in the industrial ecosystem in both countries as well as their strong dependence on Germany; even so, they have very different export profiles and relatively opposing trajectories in terms of vehicle manufacturing. In Section 2, we look at the main characteristics of the Romanian and Polish car markets. Incomparable in terms of size they may be, but they have many similarities, in particular the structuring role of imported second-hand cars, the marginal share of battery electric vehicles (BEV) in new car sales as well as poor networks of charging stations. More generally, through the examples of Poland and Romania, we illustrate the already visible risk of a two-track Europe in the race for decarbonisation, with widening east-west inequalities. Section 3 examines data on emissions from the perspective of the environment as well as the markets for electric vehicles (EVs) in Poland and Romania, together with developments in the charging infrastructure. In Section 4, we analyse the challenges of electrification in Poland and Romania, based on original equipment manufacturer (OEM) strategies and forecast data that suggest a significant relative delay of the EV transition for both countries, while also looking at some projects which are underway in the field. Section 5 sums up the expected employment effects of electrification. Even if the impact might be limited in vehicle assembly plants, it could be strongly negative in powertrain, transmission and ICE-related component manufacturing plants, putting many thousands of jobs at risk in the medium term. Section 6 concludes.

1. Industry overview

Similar to other central and east European countries within the EU, the automotive industry in Poland and Romania has grown over the past two decades into each country's largest manufacturing industry. In both countries, the industry created nearly a fifth of manufacturing value added before Covid-19 (Figure 1). While this might be significantly higher than for most western countries with large automotive industries, with the exception of Germany, it is considerably lower than for Czechia, Slovakia and Hungary. The case of Czechia is indeed exceptional — in terms purely of value added, its automotive industry is twice the size of Romania's and almost 50 per cent larger than Poland's. It is not a surprise that the Polish and Romanian industries are larger than those in other CEE countries – Poland and Romania are much larger countries and have much more diverse economies – but the gap to the immediately neighbouring countries widens if we consider the share of the industry in total gross value added: 1.6 per cent for Poland in 2019 and 2.5 per cent for Romania, versus over 5 per cent for Czechia and Slovakia and an EU average of 1.7 per cent.

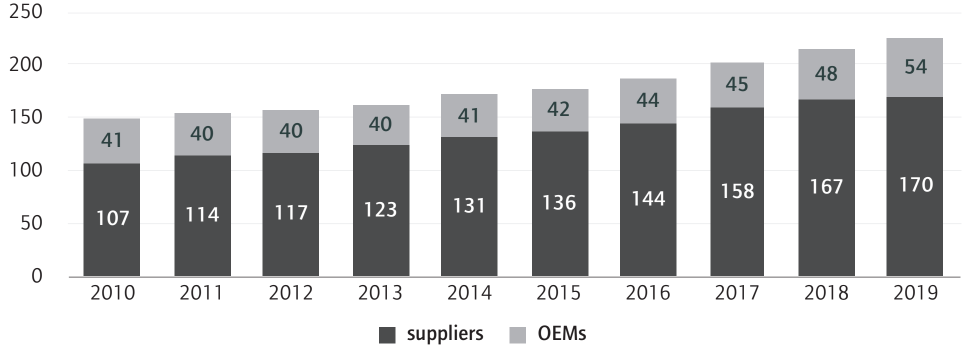
Figure 1 **The automotive industry (NACE 29) in EU countries, 2019, % of manufacturing gross value added**



Source: Eurostat.

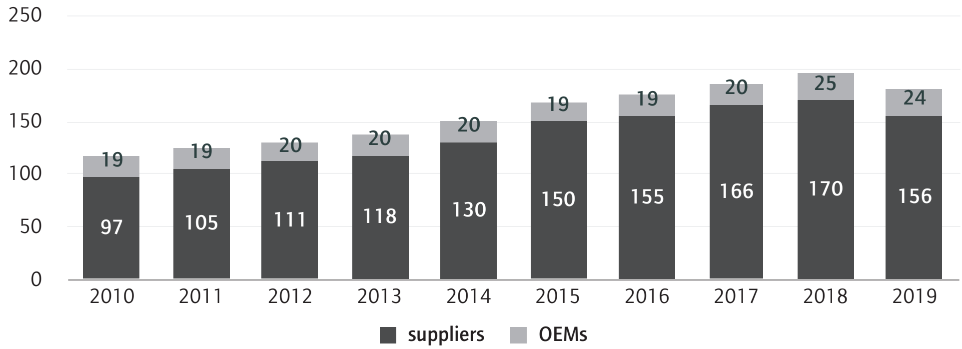
In terms of employment, the picture becomes even more nuanced. With 224 000 people employed in Poland (Figure 2.1) and 180 000 in Romania (Figure 2.2), the two countries ranked third and fifth in the EU before the pandemic when it came to the number of people working in the automotive industry, both surpassing Italy, the UK and Spain.

Figure 2.1 **Employment in the Polish automotive industry ('000 persons)**



Source: Eurostat.

Figure 2.2 **Employment in the Romanian automotive industry ('000 persons)**



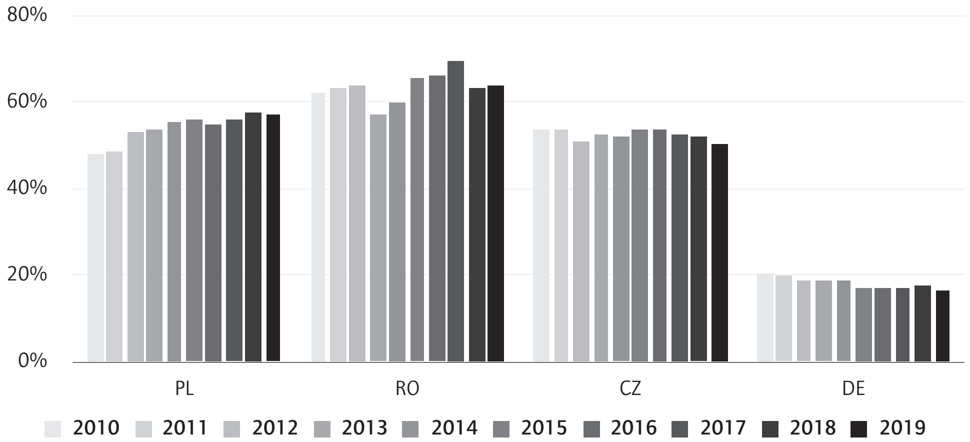
Source: Eurostat.

If we compare the size of the workforce to total manufacturing employment in each country, there is nonetheless a stark contrast between the two: in 2020, the Polish automotive workforce comprised 7.6 per cent of manufacturing employees, comparable to countries like Spain and France and far behind the well over 10 per cent figures registered in Germany and other CEE countries; in Romania, on the other hand, 15.2 per cent of manufacturing employment was in automotives, second only to the 16.2 per cent registered in Slovakia (ACEA 2022).

The value of the industry for employment in Poland and Romania grew significantly during the 2010s: in Poland, from 1.2 per cent of the total number of employees in 2010 to 1.7 per cent in 2019; and in Romania from 2.1 per cent in 2010 to a peak of 3 per cent in 2018. In comparison, employment in the German industry remained fairly stable in the context of the overall labour market, despite a 6.5 per cent increase in automotive employment between 2010 and 2019. In other words, in Poland and Romania the industry has acted as a major driving force of employment during the past decade, growing visibly faster than the rest of their economies. This is all the more remarkable given the highly dynamic trajectory of both the Polish and the Romanian labour markets especially during the second half of the 2010s — indeed, the growth of Romanian automotive employment began to lose some ground only in 2019, registering the first decline in employment in a decade.

Overall, the industrial profile of the two countries is typical of CEE, with the supplier industry being much larger than vehicle manufacturing. In 2019, 57 per cent of automotive turnover in Poland and 64 per cent in Romania was attributed to the supplier industry compared to less than 20 per cent in Germany (Figure 3).

Figure 3 **Share of suppliers in total automotive turnover**



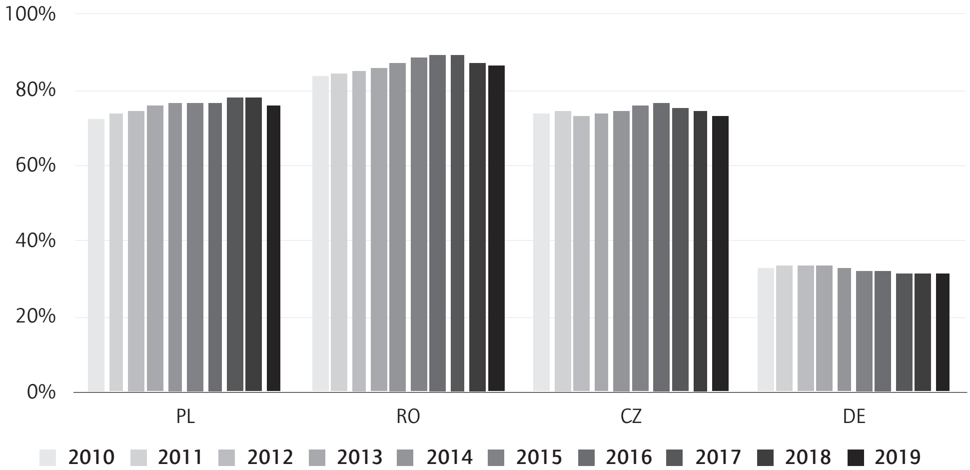
Source: Eurostat.

In terms of employment, the asymmetry is even more obvious: the supplier industry had over 75 per cent of the total number of automotive employees in Poland, and 87 per cent of those in Romania, compared to 31 per cent in Germany (Figure 4).

The Polish and Romanian supplier industries are also relatively larger than in other CEE countries — this is particularly obvious in the case of Romania. A specific feature of Poland and Romania in the CEE automotive landscape is that the supplier industry is not just significantly larger than vehicle assembly, but it has continued to grow faster; this is not the case with Czechia or Slovakia, where the combined share of suppliers began to decrease in the second half of the 2010s (Guzik et al. 2020). In 2019, Poland and Romania ranked second and third in the EU when it came to the number of employees in the automotive supplier industry; only Germany had more people working in the industry's supply chain.

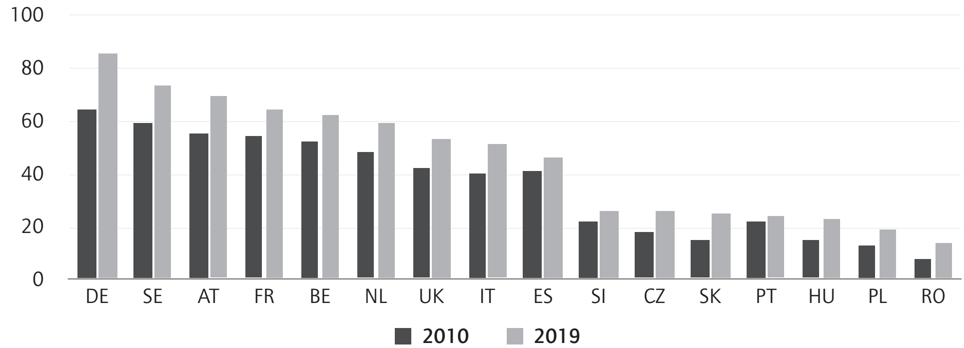
This high share of suppliers in Poland and Romania, and the contrasting development to countries like Germany, are part of the broader growth of transnational automotive supply chains in Europe and the accompanying east-west specialisation. Differences in labour costs between countries have undoubtedly been the main driver of this, with Poland and Romania having the smallest average labour costs in the EU automotive industry (Figure 5).

Figure 4 **Employment in the automotive supplier industry (% of total automotive employment)**



Source: Eurostat.

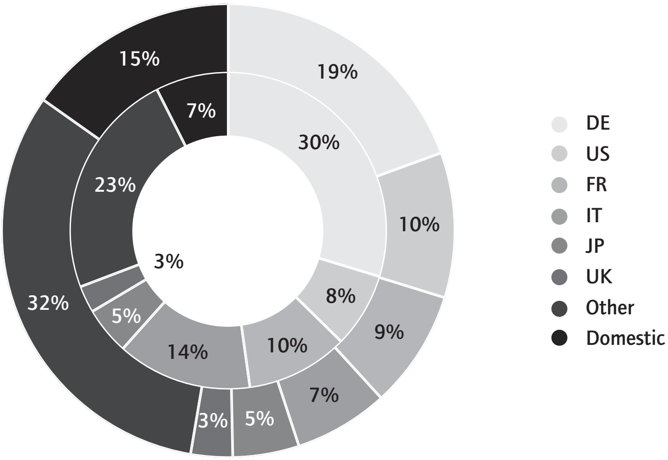
Figure 5 **Average personnel cost in the automotive industry (thousand EUR / employee / year)**



Source: Eurostat.

While Romania's position as the cheapest country might not be a surprise, Poland being behind Hungary might seem unexpected until we consider the different shares of the supplier industry in the two countries (76 per cent in Poland in 2019 versus 42 per cent in Hungary). The most significant comparison is the following: in 2019, an employee in the Polish automotive industry cost, on average, just 22 per cent of that of a German employee (17 per cent for Romania). While this difference has become smaller over time (it was 20 per cent for Poland vs. Germany in 2010 and 12 per cent for Romania vs. Germany), there is little reason to speak of genuine wage convergence. In absolute terms, the gap to western Europe has actually increased: if the average automotive employee in Romania was, in 2010, 57 000 euro per year cheaper than in Germany, by 2019 this cost difference had increased to 71 000 euro per year. Roughly speaking, therefore, relocating jobs to Poland or Romania has in fact become more advantageous over time, despite tight labour markets and sustained wage growth across CEE.

Figure 6 **Ownership of economic activity in the Polish automotive industry: employment (outer circle), turnover (inner circle), 2018**

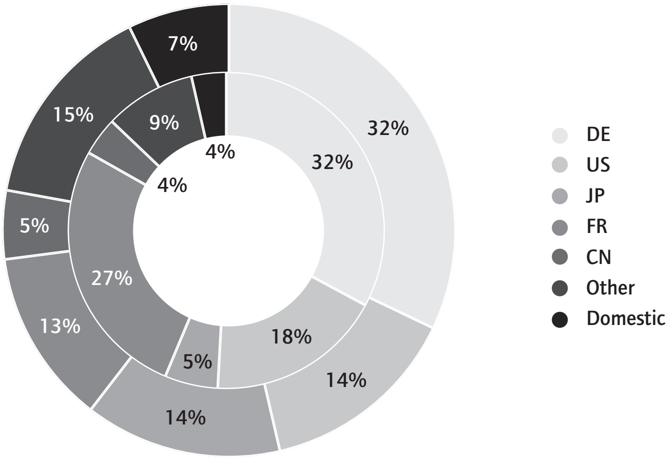


Source: Eurostat.

Catalysed by low labour costs, the Polish and Romanian automotive industries have grown primarily as a result of western foreign direct investment: only 15 per cent of industry employees worked in domestically owned companies in 2018 in Poland while in Romania the figure was lower by a factor of more than two (figures 6 and 7). German companies are the most important employers in both countries (19 per cent in Poland; 32 per cent in Romania), but North American, French, Japanese and Italian companies also have a significant presence. Contrasting the shares of employment by ownership to the shares of turnover, domestic capital shrinks to approximately half in both countries, suggesting that local firms typically have subordinate roles in the two countries' automotive industries. A significantly higher share of turnover in comparison to employment is registered for OEM-originating countries (for Poland: Germany and Italy; for Romania: France and the US), indicating much higher productivity and the impact of such activities compared to suppliers. In the case of Romania, the huge difference between the share in employment and in turnover of Japanese companies (14 per cent vs. 5 per cent) is a stark example of specialisation in low-cost parts and components. Large Japanese suppliers such as Fujikura, Takata or Yazaki have a substantial presence in Romania where they produce low value added but labour intensive products like wiring and cable harnesses.

As regards their foreign trade profiles Poland's most significant exports of automotive parts and components are for body parts (3.5 billion euros in 2019), internal combustion engines (1.5 billion) and tyres (1.9 billion); the first year of the pandemic generally had a negative impact on parts exports with the principal exception of internal combustion engines, whose export value increased by 20 per cent on 2019. As expected, Poland has a trade surplus for all major parts categories but only body parts and internal combustion engines pass the threshold of one billion euros (Eurostat 2022).

Figure 7 **Ownership of economic activity in the Romanian automotive industry: employment (outer circle), turnover (inner circle), 2018**



Source: Eurostat.

With the exception of tyres, which are a major export product for both countries, Romania's export profile is very different to Poland's. Wiring (including cable harnesses) is Romania's central export product from the supplier industry and Romania is by far the most significant producer of automotive wiring in the EU (Guga 2018). This is probably the best example of its specialisation in low cost, low value added, labour intensive manufacturing. In contrast to wiring, which hires tens of thousands of people working in a large number of plants across western and central Romania, the production of gearboxes and associated parts is concentrated in just three plants, of which only two are fully export oriented, but the sector has a comparable export significance — gearboxes and associated parts are the second largest group by export value. Crucially, the gap between the two is much larger in favour of wiring if we consider the balance of trade, which is due to gearbox imports by Ford Craiova and, possibly, to the low degree of local integration of the two gearbox plants owned by Daimler. As opposed to Poland, Romania is not a major exporter of internal combustion engines as the two engine plants in the country are captive to local OEMs. It does, nonetheless, export combustion engine parts such as pumps.

Vehicles are the single most significant export product for both countries, with some crucial differences. First, Polish exports of utility vehicles are very significant whereas in Romania they are negligible. Second, Romanian passenger car exports have grown continuously during the past two decades while Polish exports peaked before 2015; indeed, in 2020 Romanian exports surpassed those of Poland in value. There are also significant differences when it comes to the balance of trade for passenger cars: Polish imports far outweigh exports whereas Romania has registered an increasingly large trade surplus. This is partly explained by the decline in Polish passenger vehicle production during the past decade and the significant increase of production in Romania; but differences between the two countries' automotive markets also play a role — for example, Romania's small market for new vehicles (see next section for details).

A third of Poland's exports of car parts and 45 per cent of Romania's go to Germany, which is the most critical trade partner for both countries. If we include other CEE countries where German OEMs have vehicle assembly operations (Czechia, Slovakia, Hungary), then the significance of German supply chains for Poland and Romania takes on even more weight. Integration into German supply chains far outweighs the impact of OEMs' local presence: Romania's exports to Russia, France, North Africa and Turkey are strongly tied to the supply chain of the Renault-Nissan-Mitsubishi Alliance but, even when combined, they pale in comparison to the size of exports to Germany.

Table 1 **Light vehicle assembly plants (thousand vehicles)**

Country	Plant	Group	2008	2014	2019	2028 (forecast)
Poland	Gliwice	Stellantis (PSA/GM)	172	94	92	100
	Tychy	Stellantis (FCA)	493	296	263	224
	Poznan	VAG	186	171	178	124
	Września	VAG	0	0	88	64
		TOTAL	**893**	**560**	**621**	**512**
Romania	Craiova	Ford	2	68	141	234
	Mioveni	Renault-Nissan (Dacia)	243	334	350	366
		TOTAL	**246**	**402**	**490**	**599**

Source: IHS Markit.

With the Stellantis merger, Poland now has only two OEMs present on its territory, the same as Romania (Table 1). Historically, the largest Polish vehicle plant has been FCA Tychy, whose volumes nevertheless declined from nearly 500 000 vehicles per year at the end of the 2000s to just above half that ten years later. IHS Markit forecast data indicates that the Tychy plant will continue to decline slightly toward the end of this decade. The Volkswagen group is expected to have stable production volumes, the major change being the partnership with Ford with whom VW has agreed to produce light commercial vehicles (LCVs) in its Polish plants. Increased volumes at both Ford Craiova and Dacia Mioveni mean that, in time, Romania will overtake Poland in terms of vehicle production volumes.

The IHS Markit forecast assumes both Romanian plants will be working at full capacity in the next years, possibly with a capacity increase at Dacia — total current capacity in Romania is of around 550 000 vehicles (350 000 at Dacia and 200 000 at Ford). In Poland, on the other hand, total capacity is closer to one million vehicles per year on top of which come the country's significant heavy commercial vehicles operations. The forecasts thus indicate that Romanian plants will work at full capacity while Polish ones will face some capacity utilisation issues.

Table 2 **Automotive R&D personnel and expenditure**

		2011	2015	2019
Total R&D personnel (FTE)	**DE**	90 829	108 134	139 331
	PL	938	3149	6419
	RO	593	2277	2985
Researchers (FTE)	**DE**	57 057	68 466	92 837
	PL	359	2242	4551
	RO	306	632	1316
R&D expenditure (euros / capita)	**DE**	203	264	340.3
	PL	1.2	4.3	10.5
	RO	2.6	4.8	8.3

Source: IHS Markit.

In Romania, both Dacia and Ford have their own engine plants on the same sites as vehicle assembly which, in 2019, produced a total of 627 000 units (527 000 in Mioveni, 150 000 in Craiova); Dacia also produced 504 000 gearboxes in its highly integrated plant in Mioveni. The only other powertrain capacities in the country are Daimler's two gearbox plants in Cugir and Sebeş which, combined, produced 777 000 gearboxes in 2019. In comparison, Poland is a much smaller transmission manufacturer, with only one plant, in Wałbrzych, owned by Toyota (520 000 units in 2019). It has, however, much higher combustion engine production capacities with over 1.7 million engines being produced in 2019 in six plants: Jawor (Daimler, 31 000 units); Bielsko Biała (Stellantis, 282 000); Tychy (Stellantis, 220 000); Jelcz-Laskowice (Toyota, 162 000); Wałbrzych (Toyota, 220 000); and Polkowice (VAG, 797 000).

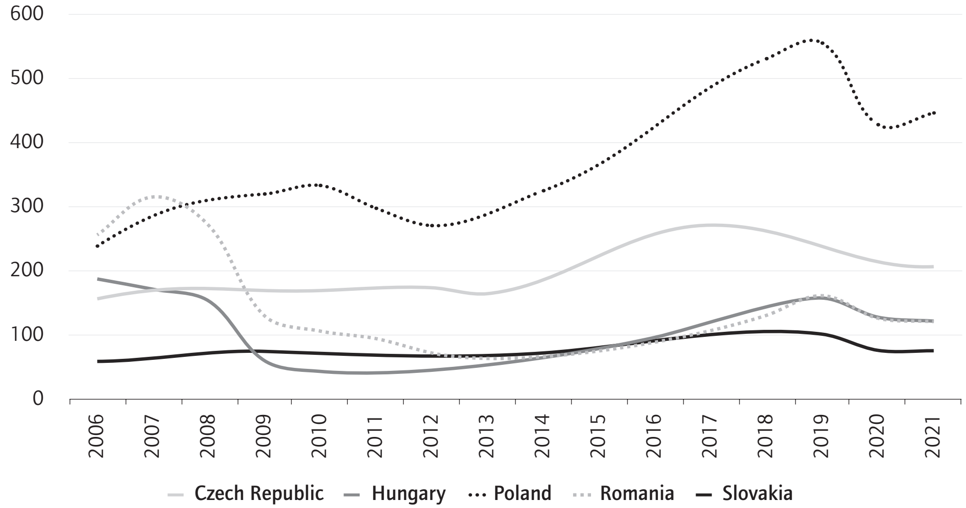
Similar to the supplier industry, these plants function primarily as production locations for export, with companies making very limited investments in non-production activities such as R&D. The comparison to Germany is striking: whereas in 2019 Germany produced eight times more light vehicles than Poland and ten times more than Romania, its R&D personnel was 21 times more numerous than in Poland and 47 times more so than in Romania (Table 2). Even though automotive R&D has increased visibly in both Romania and Poland, the growth of German R&D has outmatched this.

As in other respects mentioned above, it is unrealistic to speak of east-west convergence despite some degree of industrial upgrading in eastern countries. Such major differences are apparent when it comes to the structure and growth trends of domestic vehicle markets. For the future, they could suggest different implications for Poland and Romania when it comes to the electric vehicle transition.

2. Market overview

The Polish automotive market remains by far the largest in the CEE region in terms of sales, as Figure 8 shows. It stands as the sixth biggest market for passenger cars in Europe, yet its sales volumes are still significantly lower than those of the European 'big 5' countries. Registrations of new cars in Poland reached 556 000 units in 2019, a peak year for the European market, before Covid-19 caused it to plummet. In comparison, Spain, the smallest of the 'big 5', recorded over twice as many sales the same year, with 1.3 million new car registrations. With about 162 000 new car sales in 2019, the Romanian market is three times smaller than the Polish and ranks third among CEE countries behind the Czech Republic (250 000). Poland is also the sixth largest market in Europe for light commercial vehicles, with around 74 000 units sold in 2021, while the Romanian market is almost five times smaller with around 16 000 units sold that same year. Since Poland's population is twice the size of Romania's, the Romanian market is considerably smaller than the Polish in both absolute and relative terms.

Figure 8 **New car registrations in main CEE markets (thousands)**



Source: Syndex (data: ACEA).

Before the Covid-19 crisis, new car sales in both countries had strong momentum: between 2013 and 2019 they almost doubled in Poland and almost tripled in Romania, showing impressive compound annual growth rates of 11.5 per cent and 18.7 per cent respectively compared to 4.2 per cent across the EU, the United Kingdom and EFTA combined.

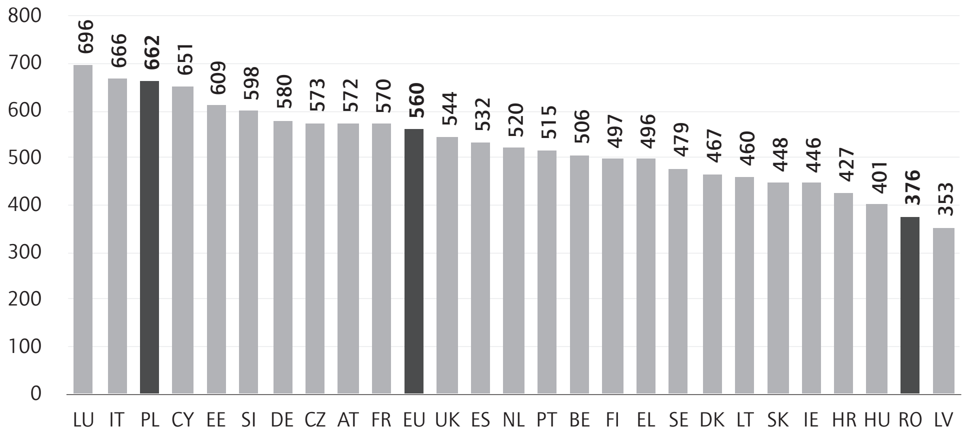
The Romanian and Polish markets were not spared by the Covid-19 crisis, with new car sales dropping by 23 per cent and 22 per cent respectively in 2020, highly similar to the decline in the European market (24 per cent). In 2021, in the context of the worsening semiconductor crisis that led to a further decline in sales in Europe (1.5 per cent), these two markets experienced opposite trajectories: the Romanian market fell by 4.1 per cent whereas the Polish market grew by 4.3 per cent, driven by increased sales of hybrid vehicles.

Primarily due to lower disposable incomes in the CEE region compared with western European countries, Poland and Romania are at the bottom of the European ranking in terms of new car registrations per 1000 inhabitants (see also Pardi, this volume). In

2019, this ratio was only 8/1000 in Romania and approximately twice that in Poland (15/1000), compared with an average of 30/1000 for Europe. For example Belgium, whose market size is comparable to that of Poland in volume (550 000 registrations in 2019), stood at 48/1000, three times more than in Poland. Almost one in three Polish households (29 per cent) and more than half of Romanian ones (54 per cent) did not own a vehicle in 2020 compared, for instance, to only 15 per cent in France.

Looking at passenger cars in use per 1000 inhabitants (see Figure 9), Poland remains more motorised than Romania with an average of 662/1000 in 2020 compared to only 376/1000 in Romania. The latter is one of the lowest rates in Europe, where the average reached 560/1000. It should be noted, however, that Romania recorded the strongest growth in this indicator in 2020, with an increase of 12 per cent against 3.1 per cent for Poland and 0.9 per cent for the EU average.

Figure 9 **Vehicles per 1000 inhabitants in Europe (2020)**



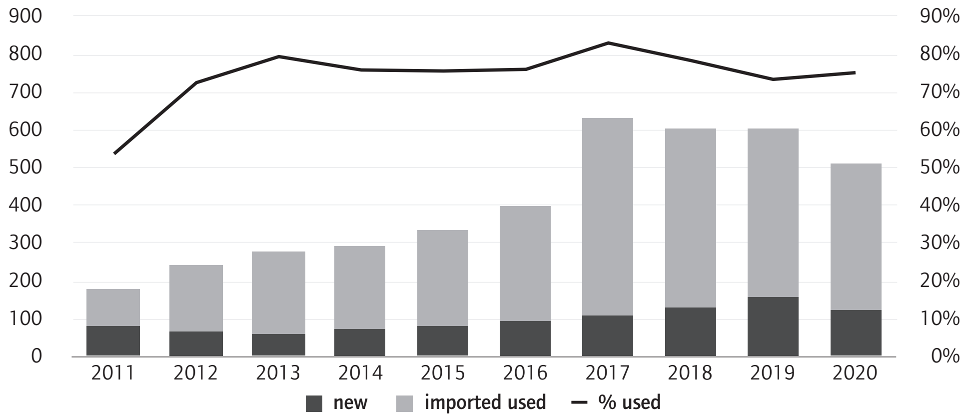
Source: Syndex (data: ACEA).

In Poland, commercial use accounts for as much as 77 per cent of new car sales in Poland, way above the European average of 57 per cent recorded in 2019 according to a Dataforce study by Transport & Environment (2020), illustrating the low weight of households in the dynamics of new car registrations in the country. This figure also explains the major role played by leasing services in the local new car market financing industry. More generally speaking, the limited purchasing power of households in CEE is hampering the local growth potential for new car sales while, at the same time, from a socio-cultural perspective, car ownership remains a strong structuring factor of social status for many citizens in CEE countries. As a combined effect of these factors, the growth of vehicle car fleets in both Poland and Romania remains largely driven by imports of used vehicles, mainly coming from Germany.

Imported used cars also play a structuring role in the expansion of both countries' vehicle fleets. The financial constraint weighing on households naturally works in favour of the second-hand vehicle market.

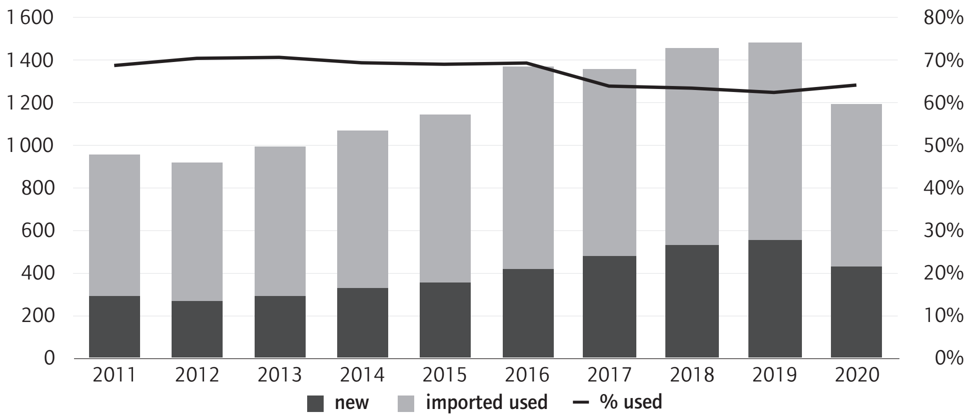
The significant share of used vehicles imported into Poland and Romania (see figures 10.1 and 10.2) makes their vehicle fleets among the most polluting in Europe. In Poland, the ratio between the number of imported used vehicles and the number of new car registrations was over 60 per cent in recent years. This ratio exceeded 70 per cent in Romania, where the abolition of the national vehicle tax ('environmental stamp') boosted imports of used vehicles in 2017 and led to an increase of almost 10 per cent in the local car fleet (Romania Insider 2022).

Figure 10.1 **New passenger car registrations vs. imported used cars in Romania (thousands)**



Source: Syndex (data: ACEA).

Figure 10.2 **New passenger car registrations vs. imported used cars in Poland (thousands)**



Source: Syndex (data: ACEA).

More importantly, in 2017, only a couple of years after the Dieselgate scandal broke, Romania imported 520 000 second-hand cars, of which 370 000 (70 per cent) were old and highly polluting diesels, according to ICCT (see Table 3). The same year, Poland imported as many as 859 000 second-hand cars about 40 per cent of which were also old and highly polluting diesels (Table 4).

Table 3 **Second-hand cars and their composition imported in Romania**

Romania (Year 2017)	Total number of cars imported	Number of diesel cars imported	Average diesel Nox emissions (mg/km)
All imported cars	520 000	369 100	1 014
Pre-Euro 1	2 900	700	1 339
Euro 1	10 300	3 900	1 339
Euro 2	79 300	38 700	1 149
Euro 3	228 700	153 600	1 029
Euro 4	132 900	112 200	951
Euro 5	59 900	55 400	1 029
Euro 6	5 900	4 500	415

Source: ICCT.

Table 4 **Second-hand cars and their composition imported in Poland**

Poland (Year 2017)	Total number of cars imported	Number of diesel cars imported	Average diesel Nox emissions (mg/km)
All imported cars	859 000	355 200	1 000
Pre-Euro 1	5 600	560	1 339
Euro 1	9 700	1 200	1 339
Euro 2	80 100	12 300	1 149
Euro 3	284 200	87 900	1 055
Euro 4	324 000	160 200	965
Euro 5	123 400	79 300	1 073
Euro 6	31 900	13 800	480

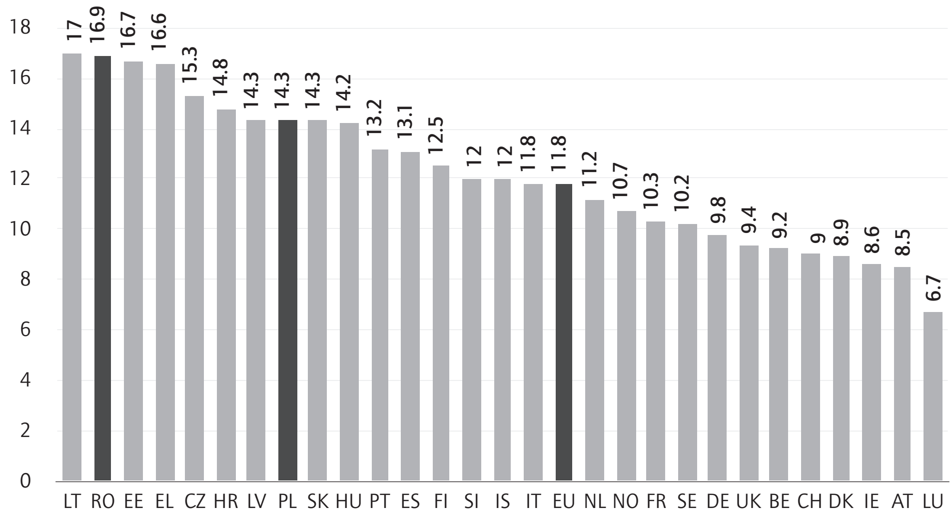
Source: ICCT.

This situation perfectly illustrates the way in which an element of car pollution has been exported from western Europe to the CEE region in the context of stricter engine standards in the wake of Dieselgate. It also tends to deepen the already significant inequalities between western European countries and those in CEE in the race for decarbonisation, as we already see the risk of a two-track Europe emerging on the horizon in the strategic field of car electrification.

Polish and Romanian vehicle fleets are also among the oldest in Europe. In 2020, the average age of passenger cars in use in Romania reached 16.9 years, one of the highest figures in the EU where the average stood at 11.8. Poland fell between these two with an average of 14.3 (see Figure 11). In comparison, the average age of cars in use in France was 10.3 years and in Germany it was 9.8.

At the end of 2020, vehicles over ten years old represented 80 per cent of cars in use in both Poland and Romania. Furthermore, almost one in four (24 per cent) was a vehicle over 20 years of age in Romania and almost one in two in Poland (40 per cent); the share of this age class has been continuously growing over the last decade.

Figure 11 **Average age of cars in use in Europe in 2020 (years)**



Source: Syndex (data: ACEA).

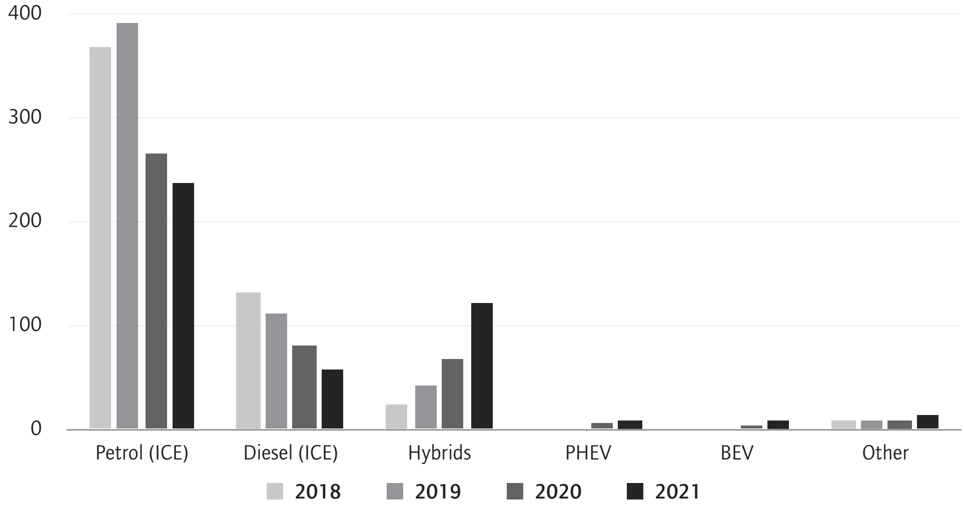
In 2020, the share of diesel represented 44.5 per cent of the approximately seven million cars in use in Romania and more than 40 per cent of the 25 million in Poland, compared to 43 per cent in the EU. In Poland, liquid petroleum gas vehicles still represent 14 per cent of the fleet. In 2020, diesel accounted for 87 per cent of the 850 000 LCVs in use in Romania and 87.7 per cent of the 2.8 million in Poland, slightly below the EU average of 91.2 per cent, in a segment where electrification is still in its infancy.

3. Environmental impact

CO_2 emissions from newly registered cars remain well above the European average in both countries. While in 2020 the average CO_2 emission of new cars registered across the EU/UK/EFTA (excl. Switzerland) region was 107.8g CO_2/km, this figure reached 115.4g in Romania and as much as 125.0g in Poland, one of the worst scores in Europe. This number is not a surprise considering the strong appetite of Poles for SUVs which, that year, still represented nearly 40 per cent of new car registrations in the country (ACEA 2022).

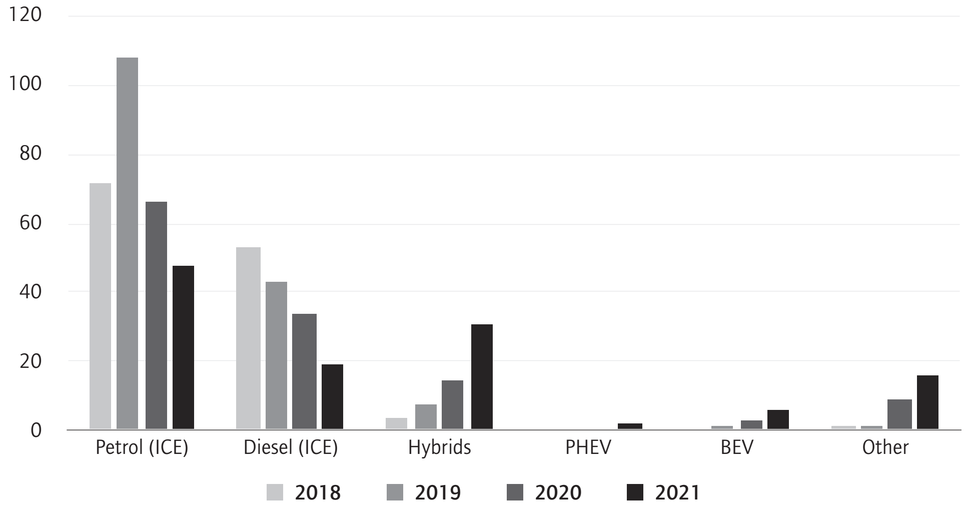
Although there has been a strong surge in mild hybrid registrations, sales volumes of BEVs and plug-in hybrid vehicles (PHEVs) are still marginal in both countries. As in most CEE countries, electrification started late in Poland and Romania in the absence of proactive policies and significant financial resources dedicated to alternative motorisations during the period before Covid-19 compared with those implemented in western and northern Europe. However, we are now seeing a sharp acceleration in the sale of hybrid vehicles in these two markets, as Figures 12 show. In Poland, these almost doubled to reach 122 000 units last year, propelling the market in the country to sixth in Europe by sales volume. The share of new hybrid registrations in Poland jumped from 15 per cent in 2020 to 27 per cent in 2021. This figure even exceeds the average recorded in 2021 for the EU/UK/EFTA region; that is, around 20 per cent. In Romania, volumes are much less significant, but sales in this segment have more than doubled, reaching 30 000 units, or one in four vehicles sold (25 per cent of new car registrations).

Figure 12.1 **New car registrations in Poland by fuel type**



Source: Syndex (data: ACEA).

Figure 12.2 **New car registrations in Romania by fuel type**



Source: Syndex (data: ACEA).

Table 5 highlights the significant relative progress made in 2021 by Poland and Romania in terms of EV sales as a share of new car sales in each market, alongside the significant drop in the sales of internal combustion engine vehicles, in comparison with the average right across the EU/UK/EFTA.

Table 5 **Change of new car sales by fuel type (2021/2020)**

Growth % 2021/20	Poland	Romania	EU+UK+EFTA
Petrol (ICE)	-10.5%	-28.5%	-17.4%
Diesel (ICE)	-28.1%	-43.2%	-33.1%
HEV	84.4%	115.2%	58.5%
PHEV	105.7%	153.9%	68.5%
BEV	94.7%	122.9%	63.4%
Other	44.6%	71.9%	29.2%
Total PCs	**4.3%**	**-4.1%**	**-1.5%**
BEV+PHEV	**100.8%**	**131.2%**	**65.7%**
HEV+BEV+PHEV	**86.2%**	**118.6%**	**61.9%**

Source: Syndex (data: ACEA).

Nevertheless, the combined share of BEVs and PHEVs in new car sales in 2021 was less than 4 per cent in Poland. In Romania, this share is, at approximately 7 per cent (of which 5 per cent were BEVs), almost twice as large, driven by strong purchasing incentive policies. In comparison, the European average was already close to 20 per cent in 2021 due largely to an impressive surge in sales in Germany. In short, Poland and Romania have started to electrify their fleets but these two markets are still weakly 'plugged-in' for the moment and, in terms of charging infrastructure, lag far behind.

In July 2021, the Polish Ministry of Climate and Environment announced a new support programme intended to reduce emissions of air pollutants by decreasing consumption of high emission fuels in transport, primarily by providing subsidies for the purchase or lease of zero emission vehicles with a value of up to 50 000 euros (225 000 złoty). This plan provides subsidies of a maximum value of approximately 4200 euros (18 750 złoty) for individuals and approximately 6000 euros (27 000 złoty) for companies.

The Polish Law on Electromobility and Alternative Fuels from 2017 provided exemptions on excise taxes for the purchase of BEVs and PHEVs (with engine sizes of 2000cc or less) which were extended until the end of 2022. According to this law, the Polish government initially set a target of one million electric vehicles on Polish roads by 2030, although its Strategy for Sustainable Transport Development has since lowered this to 600 000 electric and hybrid vehicles (IEA 2020).

In 2021, the Romanian Ministry of Environment doubled the budget for its Rabla Plus programme, which offers subsidies for the purchase of electric and hybrid cars, to around 82 million euros. Under the programme, BEVs are subsidised to the value of 10 000 euros (50 000 lei), PHEVs (≤50g CO_2/km) to one of 4000 euros (20 000 lei) and hybrids to 600 euros (3000 lei). A scrappage bonus of 1300 euros (6500 lei) is also granted for vehicles older than eight years, while electric vehicles are exempt from registration tax. Romania also provides a contribution of a maximum 2500 euros for charging stations (< 22kW) and 30 000 euros for fast charging points (> 22kW).

Poland's and Romania's charging infrastructures are among the least developed in Europe. According to the European Alternative Fuels Observatory (EAFO 2021), at the end of 2020 Poland had around 1700 charging points and Romania around 500 compared to nearly 45 000 in Germany and in France and 66 000 in the Netherlands. Looking at the number of charging points per 100 kilometres of road, Poland and Romania have some of the worst ratios in Europe (Table 6), of 0.4 and 0.5 respectively at the end of 2020 compared with 19.4 in Germany and 47.5 in the Netherlands, a country eight times smaller than Poland and six times smaller than Romania.

Table 6 **Charging points installed per 100 kilometres of road in the EU by the end of 2021 (ACEA)**

Top five countries with most chargers per 100km of road in 2021	Top five countries with most chargers per 100km of road in 2021
Netherlands (47.5)	Lithuania (0.2)
Luxembourg (34.5)	Greece (0.2)
Germany (19.4)	**Poland (0.4)**
Portugal (14.9)	Latvia (0.5)
Austria (6.1)	**Romania (0.5)**

Source: ACEA.

At the end of 2021, the number of publicly accessible EV charging points in Europe increased by 46 per cent to about 360 000 units, while the current average ratio of 22kW-equivalent publicly accessible charging points installed per 1000 passenger cars on the road was estimated to be 1.9. This ratio still varies widely between countries, with Romania and Poland showing some of the lowest figures among European countries with respectively 0.3 and 0.4. In comparison, the leading markets at the end of 2021 were Norway (20), Netherlands (8.3) and Iceland (7.6), which once again illustrates the huge gap between western Europe and CEE countries in the race for electrification (ACEA 2022).

4. Electrification prospects and impact on the automotive value chain

4.1 Vehicle assembly

The most recent forecast available suggests a significant delay in the EV transition for the automotive industries in Poland and Romania in comparison to Europe as a whole (IHS Markit 2022). Such an assessment is far from surprising given the relatively limited market potential for still expensive EVs and the specialisation of Poland and Romania in smaller and cheaper vehicles which are not a priority for electrification (Pavlínek 2022). The share in total production volumes of light vehicles that are full hybrid and pure electric is forecast to remain below 50 per cent by 2028 in both

Poland and Romania compared to almost 70 per cent in Europe. According to this forecast, Romania would produce more full hybrid vehicles (BEV: 16 per cent share of production) and Poland more fully electric ones (BEV: 24 per cent share). Both countries already produce mild hybrid vehicles which are expected to become the main powertrain option in the second half of this decade. By 2028, light internal combustion engine vehicles (ICEV) would comprise just 11.5 per cent of production in Romania and 7.3 per cent in Poland versus less than 3.6 per cent in Europe overall.

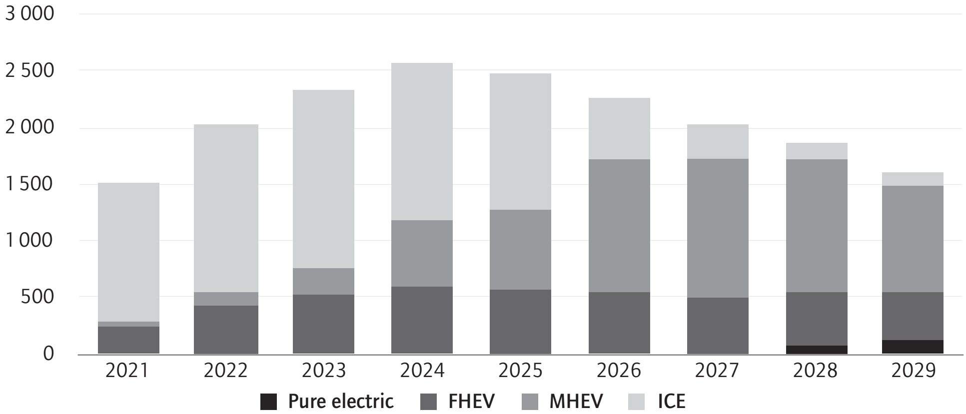
In Romania, Ford has announced it will produce a light commercial vehicle with a pure electric powertrain option starting from 2024, although this is expected to have only limited initial volumes. In the longer run, starting from 2030, Ford has announced the intention of producing only pure electric vehicles in Europe. These plans of course include the Craiova plant and we can assume that the next Puma, coming in the second half of the decade, will have an electric option from the start. For Dacia, management has been explicit about its intentions to delay electrification as long as possible since the still high cost of EV technology poses significant challenges to Dacia's low-cost business model. However, in February 2022 Renault announced it would launch a pure electric Dacia vehicle in 2024, although it remains to be seen whether it will be produced in Romania or elsewhere. For now, the brand's only battery electric vehicle, the Spring, is imported from China. In the absence of high volumes, a scenario in which a pure electric Dacia vehicle is produced elsewhere in Europe is a very real possibility.

In Poland, starting in 2022, Stellantis will produce small electric SUVs and mild hybrids (Fiat, Jeep, Alfa Romeo) in Tychy (300 000 units expected at full capacity). The three vehicles, all based on its Common Modular Platform, will be equipped with PSA engines and transmissions. The Stellantis plant in Gliwice has been converted to LCV production and it will produce ICE and electric versions of the Peugeot Boxer, Citroën Jumper, Opel Movano and Fiat Ducato (100 000 units expected at full capacity). Volkswagen is already offering electric versions of its Caddy, Transporter and Crafter models produced in Poland (the Crafter at Września where there has been major new investment). The rising share of LCVs in Poland's light vehicle assembly can explain the limited share of pure electric vehicles in the IHS Markit forecast since the pace of electrification for LCVs has, so far, been significantly slower compared to passenger cars.

4.2 Powertrain and transmission manufacturing

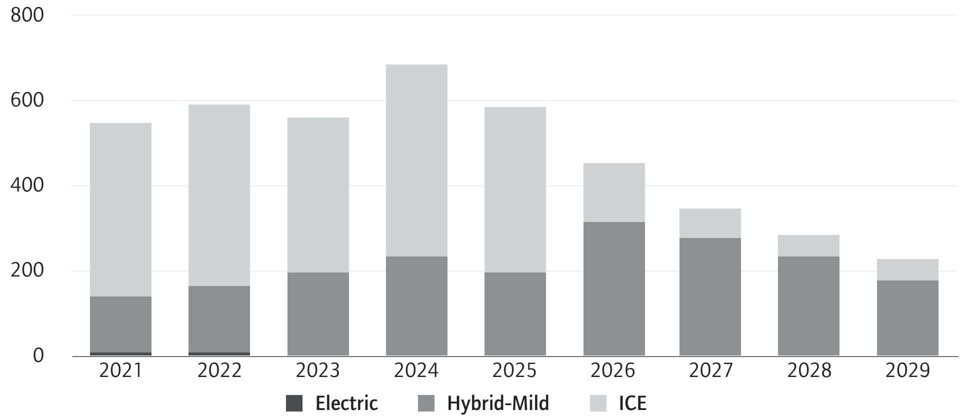
Regardless of the pace of electrification, vehicle assembly plants in Poland and Romania should not be affected in the long term. Indeed, IHS Markit forecasts show no major decline in volumes which means assembly employment should remain stable or even increase in Poland. The same cannot be said for powertrain plants. In Poland, the IHS Markit (2022) forecast indicates that engine production will peak in 2024, with volumes growing at the Daimler Jawor, Stellantis Tychy and Toyota Jelcz-Laskowice plants (Figure 13.1). Starting in 2025, Polish engine production volumes are expected to decline gradually, dropping back to 2020-21 levels by the end of the decade. The decline is expected to be more dramatic in Romania, with both of the country's captive engine plants producing significantly lower volumes by the end of the decade, with a strong decline after the 2024 peak (Figure 13.2).

Figure 13.1 **Poland: engine production volume forecast by type ('000)**



Source: Syndex based on ACEA data.

Figure 13.2 **Romania: engine production volume forecast by type ('000)**



Source: Syndex based on ACEA data.

Behind these forecasts lie several factors. First, the sourcing of EV powertrains from OEMs' core countries: Germany for VW and Ford; France and Italy for Stellantis. Second, captive engine plants (VW Polkowice, Ford Craiova, Dacia Mioveni) are forecast to convert from ICE to mostly mild hybrid engine production at lower volumes (figures 13.1 and 13.2), with OEMs sourcing most of their full hybrid powertrains from other sites. Third, export opportunities would dwindle as pure electric vehicles gain market share in Europe and while Polish and Romanian engine plants do not make the transition to pure electric powertrain production.

The situation is yet more complicated for transmission plants. Predominantly, pure electric vehicles have transmissions integrated into their electric drive units, which means that plants specialising in transmission manufacturing face a highly uncertain future. Indeed, forecasts from February 2022 show a significant decline in transmission production volumes during the second half of this decade, with the two Romanian plants especially affected by the shift to electrified powertrains. The Polish Toyota plant in Wałbrzych is more protected due to the company's early transition and continued commitment to hybrid powertrains. In Romania, Dacia transmission volumes are expected to decline with the shift to full hybrids, which is not surprising if local engine manufacturing does not itself transition to full hybrids. For Daimler's transmission production in Romania, the prospects are even worse since the group is likely to make a full EV transition faster than OEMs operating in lower price segments, while its operations in Romania are geographically isolated from the group's vehicle assembly plants. Due to this latter factor, a transition to e-drive manufacturing is difficult to envisage since it is unlikely that bulky and heavy e-drives would be shipped in large volume over long distances. Conversion to smaller parts for EV powertrains might still be an option, but this would in any case be a downgrade for Romania in terms of complexity and value added.

Undeniably, Poland remains a step ahead of Romania when it comes to the development of the electromobility supply chain. First, it should be remembered that, over the years, Poland has developed a major industrial base in the field of bus manufacturing, with the presence of OEMs like Man, Scania, Volvo, Autosan, Solaris and Ursus. In recent years, local OEMs such as Solaris and Ursus have been strongly encouraged to electrify their product portfolio and thus to consolidate their local suppliers. This has stimulated the formation of e-clusters in the context of strong demand for electric buses driven by the necessary modernisation and decarbonisation of public transport fleets.

4.3 Battery manufacturing

On the positive side of the BEV supplier industry, battery manufacturing offers job creation opportunities in the BEV value chain.

The investment by LG Chem in a gigafactory near Wrocław, the biggest in Europe by capacity so far (18 GWh currently), has made Poland one of the leaders in power storage manufacturing in Europe. Ultimately, the total plant capacity is expected to reach 70 GWh which would enable LG to supply the equivalent of approximately 1.4 million battery packs for BEVs (based on a 50 kWh battery pack) and provide about 6000 jobs. This investment, as well as those from SK Innovation (ultimately 1000 jobs) and Umicore (400 jobs) in cathode material manufacturing and recycling capabilities, are creating a favourable environment for the further development of an EV supply chain in Poland, a country which joined the European Battery Alliance in 2019, soon after its creation.

In contrast, Romania has not recorded any significant investment in battery cell manufacturing on its territory to date. For example, the future BEV versions of Ford's models assembled in Craiova will apparently source their battery cells from Hungary, which benefits from the presence of Korean cell manufacturers Samsung SDI (3 GWh) and SK Innovation (7.5 GWh in 2022), as well as the presence of major German OEM assembly lines. As opposed to Poland or indeed Hungary, the Romanian public authorities have so far shown limited interest in developing local large-scale battery manufacturing operations. Even the National Recovery and Resilience Plan is vague on this subject, aiming to foster the growth of local battery manufacturers but without any clear targets or assessments of viability. At present, the only battery specialist in Romania is Rombat, which has historically produced 12V vehicle batteries and which is now trying to develop its capabilities in the manufacture of battery cells in collaboration with a local start-up. Rombat is, however, a relatively small company with limited financial capacity and it cannot make the sort of investments already visible in Poland. A significant increase in pure electric vehicle volumes at either Mioveni or Craiova is difficult to imagine in the absence of local battery production capabilities, but this is unlikely to happen before the end of this decade.

For Poland, the emergence of a battery supply chain can therefore be seen as a competitive advantage in the future race for electrification. However, IHS Markit forecasts suggest that Poland should remain a production centre mainly positioned on hybrid ICE technologies for the next decade. In addition, the main investments in future battery capacity are now concentrated in Germany, which is seeking to keep competences in the country. No less than ten gigafactories have been announced in Germany (between 250 and 350 GWh by 2030) to cover the future needs of the largest BEV market in Europe. Above all, however, Poland's high dependence on coal in its energy mix (70 per cent) significantly complicates the environmental equation. As a result, a scenario of a slow transition in Poland's energy mix could hamper future investments and the development of the supply chain. The government and miners' unions have reached a deal to close the last coal mine by 2049 at the latest, a year ahead of the EU's deadline for achieving carbon neutrality. Some companies in the industry in Poland, such as Volkswagen, Daimler and Umicore, have already taken several initiatives to supply their Polish factories solely with renewable energies, but local capacities are still marginal in this field. Finally, from an EV market perspective, a status quo in Poland's energy mix would involve a growing number of vehicles on the roads with a highly questionable carbon footprint. Table 7 sums up the main technology developments in the emerging BEV supplier sector in Poland.

Table 7 **EV, ADAS and energy storage developments in Poland**

Company	Development	Job creation potential
Daimler/Mercedes	Battery manufacturing and packing factory on its new engine production centre in Jawor (4-cylinder engines for ICE and hybrid vehicles). The site is set to supply all Mercedes-Benz sites in Europe and to be powered by renewable energy.	Ultimately 300 jobs for the battery operations (1000 in total)
LG	Battery plant in Biskupice with a current capacity of 18 GWh and ultimately 70 GWh.	Ultimately 6000 jobs
SK Innovation	Li-ion separator factory in Dąbrowa Górnicza which is expected to start production by 2023.	400 jobs Ultimately 1000 jobs
SK Nexilis	Copper foil factory project for Li-ion batteries in Stalowa Wola.	
SungEel HiTech	EV battery recycling facility near Wrocław.	
Enchem	Lithium salt preparation facility for EV Li-ion batteries near Wrocław.	
Capchem	Electrolyte production facility in Śrem with start of production expected this year.	
Umicore	Cathode material production plant in Nysa, which is set to be powered by Engie wind farm. Umicore also has projects in the field of battery recycling.	Ultimately 400 jobs
Elemental Strategic Metals	Li-ion battery recycling facility in Zawiercie, expected to be operational by 2023.	100 jobs
Valeo e-automotive	Manufacturing of e-motors for electric vehicles in Czechowice-Dziedzice.	
ElectroMobility Poland consortium	First made in Poland – BEV (Izera brand) to start production in Jaworzno in 2024 with a target of 150 000 BEVs per year.	3000 direct jobs (12 000 in suppliers)
Aptiv	R&D centre for ADAS technologies in Kraków	2000 engineers
Northvolt	Stationary energy storage plant in Gdańsk	500 jobs

Source: Syndex.

5. Expected employment effects

As discussed above in Section 1, the share of automotive employment in total manufacturing employment in Poland and Romania is among the highest in the EU: in absolute terms, before the pandemic the industry directly hired 224 000 people in Poland and 180 000 in Romania.

Existing assessments of the employment impact of electrification vary widely. For instance, a recent PwC (2021) study for CLEPA highlights the potential job impact of an EV-only scenario. Here, based on the European Commission's 'Fit for 55' proposals for the reduction of CO_2 emissions, PwC anticipates a 43 per cent net decrease in ICE-related jobs (i.e. 203 000 job losses) between 2020 and 2040 within the EU/UK/EFTA. In Romania, ICEV employment would increase first by 57 per cent (32 000 job gains) between 2020 and 2030 (due to hybrid transition), but then fall sharply with a net loss of 49 per cent of the workforce (28 000 losses) in 2040 compared with 2020. For Poland, after a 47 per cent increase in the ICE-related workforce (26 000 gains) between 2020 and 2030, this would also drop significantly, resulting in a net loss of 20 per cent in 2040 compared with 2020 (11 000 losses).

In contrast, in a recent study on the employment impacts of electrification in Poland, BCG (2021) anticipates, in a pessimistic scenario in which it does not assume further actions regarding the local development of the electromobility sector, a 4 per cent drop in the workforce (17 000 job losses) between 2020 and 2030, including in core automotive and adjacent industries. In this scenario, OEMs and suppliers would suffer relatively significant job losses, aggregating to a decrease of 6 per cent of employment (26 000 losses), including a 14 per cent decline in ICE-focused suppliers alone (4000 losses) in a general context of depressed volumes, strong automation and job offshoring pressures. More generally speaking, BCG expects local industry to experience a deep qualitative change, rather than a substantial quantitative one, with potentially major challenges related to employment transition towards adjacent industries (relocation, reskilling, retraining, etc.).

Electrification should not have a negative impact on employment in vehicle assembly plants. Indeed, since vehicle production volumes are forecasted to increase in both countries, we can expect employment also to increase, perhaps less visibly in plants that, today, have a relatively low level of automation, such as Dacia. If current forecasts prove realistic, however, the impact of electrification should be strongly negative for employment in powertrain plants in both countries. In Romania, Daimler's two transmission plants employ around 3000 people, Ford has approximately 1000 people working in engine assembly in Craiova and 4000 people work in Dacia's powertrain plant. Overall, around 8000 jobs (or 4.4 per cent of total automotive employment) are directly at risk in a full electrification scenario and if no pure electric powertrain capacities are developed in Romania. Such a scenario is actually highly unlikely, since both Ford and Dacia should, in any case, maintain some powertrain employment (in battery pack assembly, for example). Strictly based on volume forecasts, employment in engine manufacturing could decline by as much as 70 per cent by 2028. The impact on transmission manufacturing employment could be even more severe (a drop of 75 per cent by 2028), with comparatively worse prospects in the longer term. The potential loss of these jobs would have significant negative implications beyond these numbers since these are highly complex activities in comparison to the rest of the Romanian automotive industry.

Beyond engine and transmission plants, the impact of electrification for suppliers present in Romania is difficult to assess with precision. Looking at Romania's automotive export profile, apart from gearboxes, components which are directly tied to ICE powertrains (ICE pumps, exhaust components, radiators, filters, ignition parts) have a low share in total exports. Wiring and cable harness manufacturing is the most significant export product and is also by far the most important sector in terms of employment. Even if much of the wiring produced today is for ICE powertrains, electric vehicles will require more wiring, and certainly not less, which means there is no automatic risk to these jobs in Romania. Some job losses might happen, however, if companies decide that product changes bring opportunities to relocate production in countries with even lower labour costs, such as Moldova or Serbia, where the automotive wiring industry has been growing in recent years.

The impact of powertrain electrification on direct employment in Romania in the industry should be limited from a quantitative point of view, even if some job losses are unavoidable in the light of forecasts showing no substantial investments in EV powertrain manufacturing capacities. The immediate and direct impact would primarily concern engine and gearbox plants. Indirectly, electrification could offer companies an opportunity to reshuffle their investments geographically and some sites in Romania could suffer due to product reallocation.

The impact on the ground could nonetheless be severely felt given the high geographic concentration of automotive employment. In Argeș county, for example, almost 28 000 people (18 per cent of all employees) work in the industry, around half of them being directly employed by Dacia. The two Daimler gearbox plants are in Alba county, which has a relatively low share of automotive employment (4.3 per cent). Other counties in the central and western regions of the country are much more heavily dependent on automotive employment and, even if there is no clearly visible risk for most of them at this time, the lack of a clear approach to the challenges of electrification on the part of both the regional and the central authorities raises some concern. In contrast to OEMs, most suppliers have limited sunk investments and have, so far, focused on pure assembly operations based on labour cost advantages. Moreover, many of the initial investments were generously subsidised via state aid, with the government pursuing purely quantitative employment targets. These companies thus have limited incentives to pursue potentially costly large-scale transformations, while the government would have to consider qualitative industrial transformation goals and possibly make significantly larger funds available. For the moment, such possibilities are entirely theoretical.

For Poland, a full electric scenario after 2030 would also put at risk thousands of jobs for the powertrain plants currently in operation. Toyota's engine plants in Jelcz-Jaskowice and Wałbrzych together employ about 3400 people (including the gearbox manufacturing activity), Stellantis employs about 1200 people in Bielsko Biała, Daimler approximately 700 people in Jawor (excluding the battery assembly activity) and Volkswagen 1200 people in Polkowice. This means around 6500 jobs are at risk at these engine plants alone, the equivalent of about 3 per cent of total automotive employment, in the case where pure electric powertrain capacities fail to consolidate. For example, at Polkowice the question of a potential site reconversion in the medium term must be taken very seriously due to its exposure to diesel. On the one hand, its geographical proximity to the electrical cluster around Wrocław provides some potential opportunities but, on the other, the complete reshuffling of Volkswagen's investments and competition with other sites (like Gyor) make its future still uncertain. In any case, an electrical conversion of the site is unlikely to mitigate the decline in the direct production workforce.

When it comes to suppliers, the picture is still unclear as many show diversified activities and are not necessarily fully exposed to ICE powertrain components, often having several plants in the country such as, for instance, Valeo (which is exposed with its alternator activity but, at the same time, well positioned on e-motors). However, from an export profile perspective, we can observe how ICE components are significant to the supply chain with a share in total exports of no less than 8 per cent. This includes exhaust parts, fuel and air filters, radiators, ignition parts, starters, generators, gearboxes, ICE pumps and clutches, worth a total of 2.2 billion euros of exports in 2020 (2.7 billion euros in 2019). Including ICE engines, the share of exports rises to 15 per cent, illustrating the prominence of ICE activities for the local automotive industry.

From a geographical point of view, the employment impacts mainly concern south-west Poland where jobs in the industry are mainly concentrated in two main regions. First, Lower Silesia where Toyota, Volkswagen and Daimler have their engine factories; it is also in this region that an electric hub is emerging around the LG gigafactory near Wrocław. Second, Silesia with the presence of Stellantis and a high concentration of suppliers such as Valeo, ZF or Nexteer Automotive. This, around Katowice, is where SK Innovation has chosen to set up its separator factory in Dąbrowa Górnicza and where Electromobility Poland is expected to start the production of the first BEV to be made in Poland.

6. Conclusion

The automotive industrial profiles of Poland and Romania are in many ways typical of central and eastern Europe: high dependency due to foreign ownership; very strong growth over the past decades, resulting in increasing economic and social importance at national level; and export specialisation driven by labour cost advantages versus western Europe. The industries of the two countries are nonetheless very different from that of Czechia, Hungary or Slovakia, the main difference being that vehicle manufacturing is dwarfed by suppliers exporting primarily to Germany. Within this landscape, Poland is highly specialised in ICE powertrain technology while Romania has become Europe's number one manufacturer of automotive wiring and cable harnesses.

Marketwise, the overall landscape in both countries is likewise typical of CEE: low sales volumes of new vehicles due to low disposable incomes; a very high share of used vehicles imported from western Europe; and aging and relatively more polluting vehicle fleets. Essentially, both Poland and Romania have become the major destinations for diesel vehicles offloaded by western Europeans in the wake of the Dieselgate scandal. At the same time, sales of electric vehicles remain subdued due to low incomes and despite substantial government incentives. The prospects of this situation being reversed are far from positive and the task has thus far proven to be beyond both governments. The very weak development of charging infrastructures compared to other EU countries is a good example of these difficulties.

Given these industrial and market features, it is difficult to imagine a scenario in which powertrain electrification (in terms of both manufacturing and sales) would not be delayed in both Poland and Romania. If for vehicle manufacturing per se we are likely to be talking about a delay of a few years, but overall the same trajectory as in western Europe, there is nevertheless much more uncertainty regarding the large supplier industry in both countries. In Poland, combustion engine manufacturing is currently highly developed and is one of the country's major export industries; while in Romania the manufacture of ICE transmissions and components has soared over the past decade. In Romania, there is little indication of any investments replacing these activities that are bound to disappear as electrification progresses. The picture in Poland is more positive, as the country already has important investments in battery manufacturing capabilities.

There are reasons why a smooth transition to electrified powertrains is bound to face particularly significant headwinds in both countries, albeit for very different reasons. While the undeniably strong degree of emerging battery competence in Poland might give OEMs an incentive and facilitate new job creation, the country's energy mix significantly complicates the environmental equation. As for fiscally weak Romania, the country could struggle to muster the necessary resources to invest in infrastructure, technology and market stimulus.

Estimates on the employment impact of the electrification of the Polish and Romanian automotive industries range from the insignificant to the dramatic. According to our own assessment, the direct employment impact of the loss of engine and transmission manufacturing would be of less than 5 per cent of total automotive employment. In the context of low-cost industrial specialisation, the loss of these jobs would be much more dramatic, since these are highly skilled and high value added jobs of which both countries are much in need. The geographical concentration of these jobs also raises major questions concerning the full social and economic impact of job losses in ICE technology manufacturing. So far, however, these questions have not sparked major public debates nor stimulated adequate policy responses.

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Glossary

ACEA	European Automobile Manufacturers' Association
ADAS	Advanced Driver Assistance Systems
AFID	Alternative Fuel Infrastructure Directive
BEV	Battery Electric Vehicle(s)
CARS 21	Competitive Automotive Regulatory System high-level group
EC	European Commission
FCEV	Fuel Cell Electric Vehicles
FTE	Full-time Equivalent
GHG	Greenhouse Gas
GWh	Gigawatt hour
ICE	Internal Combustion Engine
ICEV	Internal Combustion Engine Vehicle(s)
ICCT	International Council on Clean Transportation (NGO)
INACD	Innovators and Actors Database
IPCEI	Important Project of Common European Interest
IPR	Intellectual Property Rights
KWh	Kilowatt hour
LFP	Lithium Iron Phosphate
LiB	Lithium-ion Battery
NCA	Nickel Cobalt Aluminium
NEV	New Energy Vehicle (Chinese terminology for battery electric vehicles)
NMC	Nickel Manganese Cobalt
OEM	Original Equipment Manufacturer
PHEV	Plug-in Hybrid Electric Vehicle(s)
TEN-T	Trans-European Networks for Transport
T&E	Transport and Environment (NGO)
TIS	Technological Innovation System
VDA	Verband der Deutschen Automobilindustrie
WLTP	Worldwide harmonized Light vehicles Test Procedure
ZLEV	Zero Low Emission Vehicles

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On the way to electromobility – a green(er) but more unequal future?

Edited by Béla Galgóczi

Fast-track electrification is now the dominant way to decarbonise road transport and, from 2035, the era of the combustion engine will be history. The European automotive industry finds itself in a crucial transformation with its whole future at stake. This book investigates the main challenges with a focus on employment and seeks to identify the policy pointers towards a transition that is just. It matters less how the change of propulsion technology affects employment at an aggregate level; what is more important is how Europe can secure its global position during the reconfiguration of international value chains and how particular regions find their place in the new constellation. The first three chapters examine how ready and competitive the EU is in the global race to electromobility; while the remainder provide insights into the differential effects of this transition at Member State and regional levels.

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