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Recharging the batteries

How the electric vehicle revolution is affecting Central, Eastern and South-Eastern Europe

March 2022

European Investment Bank
The EU bank

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Recharging the batteries: How the electric vehicle revolution is affecting Central, Eastern and South-Eastern Europe
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Abstract

After spending 120 years producing and improving petrol and diesel engines, the automotive sector is on the cusp of a new and entirely electric age, at least in Europe. The combined effect of new regulations and the plans of original equipment manufacturers (OEMs) suggest that the era of internal combustion engine vehicle (ICEV) powertrains — including plug-in and hybrid models — will be finally over on the continent by 2035. Central, Eastern and South-Eastern European (CESEE) countries — largely dependent on the choices taken at the headquarters of the main automotive players — are set to be an integral part of the electrification trend in the European automotive industry and some are even projected to become electrification hubs in the future. However, they are also expected to focus on traditional powertrain technologies for longer than Western Europe.

New players are taking their place alongside incumbents and various factors are coming into play to shape the electrification of the sector in CESEE countries over the next few years, with batteries, infrastructure, the future of internal combustion engine vehicles in emerging markets and innovation among the key elements guiding the transition of the "machine that changed the world". This paper analyses the role of the automotive industry in CESEE and investigates how prepared it is for the largest structural change in his history. Particular emphasis is placed on the macroeconomic implications, challenges and risks that these countries will be facing on the road to electrification.

JEL classification: L62 Automobiles; Other Transportation Equipment; Related Parts and Equipment
Keywords: automotive, electric, battery, CESEE

Contents

Executive summary

As it stands, the future of the automotive sector looks electric, at least in Europe. The radical transformation to electric powertrain technologies comes in addition to numerous other changes driven by socioeconomic trends, increasing regulatory requirements and the adoption of emerging technologies, especially those related to vehicle automation and connectivity. After spending 120 years producing and improving petrol and diesel engines, most major automakers (original equipment manufacturers or OEMs — the main automotive producers) are phasing out new investments in internal combustion engines and announcing new targets for electric vehicle production. Europe is in the lead on electrification, with companies setting more ambitious targets for the continent than in other areas such as China and the United States (where electrification is also advancing quickly).

With automakers widening and accelerating the provision of new electric vehicle models, their adoption is gaining pace, and the market is reacting quickly. While new sales of pure electrics (BEV), plug-in hybrids (PHEV) and hybrids (HEV)[1] accounted for a mere 1% of the vehicles in circulation in the European Union in 2019, new sales of those vehicles represented 18% of total new auto sales in 2020 and 40% in the first three quarters of 2021, thanks in part to public incentives.

A series of regulations is accelerating the electric revolution, with a view to addressing climate change and the need to reduce greenhouse gas emissions. Under the European Green Deal, the European Commission is proposing the Fit for 55 package (presented in July 2021), which is aiming for a CO_2 reduction of 55% before 2030 and 100% by 2035 ("all new cars registered as of 2035 will be zero-emission" according to the legislative proposal). In addition, a new Euro 7 norm is expected to introduce even stricter exhaust emission standards, and some EU Member States have announced specific dates for a 100% phase-out of sales of new internal combustion engine vehicles (ICEVs) in the next decade. The combined effect of carbon emission regulations, market acceptance, public policies at a local level and major automakers' plans amounts to a de facto ban on the sale of new fossil fuel-powered cars in Europe, including hybrid and plug-in models, by 2035. In less than 15 years, pure electric models are set to dominate the entire range of new car sales and the large majority of cars on the roads.

Over the last two decades, the automotive sector has seen a worldwide change in production hierarchies in favour of emerging markets. This shift has been driven by both increasing local demand and the relocation of production choices of the main European, Japanese and US automakers.

Against this backdrop, Central, Eastern and South-Eastern European countries have benefited from the relocation of production from Western factories, becoming a major production base. This has led to the automotive industry gaining an important role in several countries, including the Czech Republic, Slovakia, Slovenia (which are among the top countries in the world in terms of production of cars per capita), Hungary, Poland and Romania. Backed by strong inflows of foreign direct investments in recent decades, the industry has been integrated into European and global value chains, car production

[1] Electrification can take different forms, as the family of electric and hybrid vehicles is composed of various categories: pure electric models (BEV — battery electric vehicle), plug-in hybrids (PHEVs — plug-in hybrid electric vehicles, which are leveraging both on petrol and a battery pack that can be plugged in to charge it up) and hybrid models (HEVs — hybrid electric vehicles) in which an internal combustion engine is aided by an electric motor.

numbers have risen, exports have increased strongly, and the sector has become a key growth driver for these economies.

CESEE countries remain the most automotive sector-focused in Europe. The car sector plays just as prominent a role in the Czech Republic, Hungary and Slovakia as it does in Germany, accounting for about 20% of total manufacturing. However, countries in the region often tend to be specialised in value chain functions with lower value added than those of Western economies. This means that the CESEE automotive sector has a revealed comparative advantage in the production function, whereas Germany's automotive industry specialises — despite some decline in recent years — in pre and post-production business functions with higher value added, such as headquarter services, research and development (R&D) and business services. Caught in this functional "specialisation trap", countries in the region thus tend to serve as "factory economies" in the European production networks, while Western European countries take the role of "headquarter economies".

Considering their high dependence on the strategies of major automakers and on decisions taken at their respective headquarters, CESEE automotive factories are deeply affected by the electrification trend. The large majority of the models produced in the region have been or will be electrified soon and the production of electric vehicles (EV) is quickly increasing. Going hand-in-hand with the rising production of electric vehicles is the rising significance of alternative powertrain technologies in the region's exports. The share of electric vehicles in the region's total car exports has seen a significant increase over the last few years, rapidly surpassing 20% (30% for Slovakia and Romania) of total car exports in many countries.

Recent announcements by major automakers indicate that some countries in the region have the potential to become key focal points for electric production. For instance, Slovenia, Slovakia and the Czech Republic are expected to have the highest level of electric vehicle production per population unit in 2030, according to Transport & Environment (2021). Moreover, vehicle production in some CESEE countries is projected to become exclusively (Slovenia) or predominantly (for example, Poland) focused on electric vehicles.

In addition to electric vehicle production, the region is also doing its best to secure a role in battery production, as batteries and charging infrastructure will be a key element of the transformation of the automotive sector. Their weight, costly logistics and importance in the assembly of electric vehicles mean that it is reasonable to expect the production of Li-ion batteries to be placed close to the regions where electric vehicles will be assembled, a pattern already recognisable in Europe. However, battery production is still dominated by Asian countries and China in particular (75% of global capacity), while the European Union is lagging behind (currently less than 10%, thanks exclusively to factories in Poland and Hungary). As around 20-25 new production sites for electric batteries are needed in Europe over the next ten years to serve the growing needs of automotive players, various projects in the CESEE region are already ongoing or planned. Moreover, some major automakers are establishing joint ventures with battery manufacturers or implementing vertical integration strategies.

The status of the electric vehicle charging network is one of the key determinants of sales. Around 213 000 publicly accessible chargers were deployed in the European Union at the end of 2020, around 10% of which were fast chargers. However, the distribution of charging points remains very uneven across Europe, with South Europe and CESEE countries lagging behind, and with significant gaps in the network. At least 1 million publicly accessible recharging stations must be put in place by 2025 (under

the European Green Deal) to support an expected 13 million electric vehicles, and 3.5 million stations by 2030 (Fit for 55 package) to support an estimated 30 million vehicles.

The European Union has set very demanding goals in relation to climate change and the digital agenda, whereby these domains do not just co-exist, but rather enhance each other in a so-called twin transition. While CESEE is not a main contributor to innovations tackling climate change in absolute terms, it has clearly seen wide-ranging uptake of climate-friendly patents in the transport sector. Almost 20% of the region's patents in the transportation domain are related to electric vehicles and charging, a higher share than in Western North and South Europe.

Overall, various factors will shape the electrification of the automotive sector in Europe over the next few years. Firstly, while technological advances and the growing variety of electric vehicles available are projected to make them cheaper, rising demand for and limited supply of key raw materials together with high investment and energy costs will counteract this trend, at least in the short to medium term. At the same time, the supply of internal combustion engine vehicles will continuously thin out. Secondly, the geography of battery cell production and the deployment of charging infrastructure will become crucial factors in the car industry's transformation. Thirdly, given the (new) supply chains and the geographical distribution of activities, Germany appears to be turning into Europe's new electrification hub in terms of both electric vehicles and battery production.

Its proximity to and close connections with Germany grant the CESEE region (and the Czech Republic, Slovakia, Poland and Hungary in particular) the potential to continue playing an important role in the automotive industry. In addition, pre-existing or planned battery cell manufacturing capacity is likely to help the region retain a role in a transformed automotive supply chain. The structural shift to electromobility may not be driven exclusively by traditional automakers and automotive firms that are already well established in the region. Potential newcomers — be it startups or firms from other geographical regions, particularly China — are also increasingly likely to enter the European automotive scene. Moreover, technological developments provide new opportunities for firms well beyond the automotive industry, such as those from the IT or chemical sectors.

However, while electrification is inexorably finding its way into the automotive industry in CESEE, the industry's shift to electromobility may happen at a more gradual pace than in Western European countries. This is due to persistently lower innovation capacity, the functional specialisation trap and a continued — although in light of the tight labour market, vanishing — labour cost advantage. Hence, internal combustion engine production in the region will continue for longer, increasingly serving global markets where vehicle electrification will take place only in the much more distant future. On the one hand, this may mean that countries in the region fall back from the cutting edge in terms of electric vehicle technology adoption. But on the other hand, the continued production of internal combustion engine vehicles provides a diversification opportunity and will also mitigate the negative labour, social and distribution effects of the current major trends in the automotive industry (particularly electrification, automation and digitalisation), at least in the medium term.

To this end, CESEE countries are likely to face various challenges on the road to mobility electrification. In addition to the above-mentioned prospective rises in the (real) prices of cars (both new and old), raw materials and energy, the fiscal costs of car electrification in the region could also be significant. This is not only due to the large investment needs for infrastructure (see Box 1 in Chapter 2), energy production and transmission, but also possible fiscal support to favour the uptake of electric cars among consumers on a significant scale. Experience from pioneering countries in the realm of

electromobility suggests that putting the fiscal consequences of mobility electrification on a sustainable footing without jeopardising the demand for electric vehicles turns out to be a rather tricky exercise for fiscal authorities. Additionally, close monitoring of financial sector risks is warranted in light of the emerging imbalances in the electric vehicle sector. Moreover, the transition to electromobility will have an impact on employment: electric vehicles are less labour-intensive than their internal combustion engine predecessors owing to significantly lower complexity (an internal combustion engine has some 1 200 parts, an electric engine only about 200).

Turning to the CO_2 impact of mobility electrification, holistic analyses of electric vehicle CO_2 emissions over their life cycle suggest that carbon footprint improvements will be limited in CESEE countries until their energy mix shifts significantly towards renewables.

In his novel *The Leopard*, Giuseppe Tomasi di Lampedusa wrote that "if we want things to stay as they are, things will have to change". And indeed, the CESEE automotive industry will have to change many things to maintain its dominant role. Therefore, while it is essential for countries in the region to keep the automotive industry's importance in mind and make efforts to stay integrated with the automotive core and German-driven supply chains — including by attracting R&D-intensive activities and those with higher value added — it is also important to focus attention on other promising sectors and industries of the future.

Key acronyms

ADAS	Advanced driver-assistance systems
BEV	Battery electric vehicle(s)
CESEE	Central, Eastern and South-Eastern Europe (the Czech Republic, Hungary, Slovakia, Poland, Bulgaria, Romania and Slovenia)
ESG	Environmental, social, governance
EV	Electric vehicle(s)
FCEV	Fuel cell electric vehicle(s)
HEV	Hybrid electric vehicle (s)
ICE	Internal combustion engine
ICEV	Internal combustion engine vehicle(s)
OEM	Original equipment manufacturer(s)
PHEV	Plug-in hybrid electric vehicle (s)

Introduction

The automotive sector's future looks entirely electric, at least in Europe. After spending 120 years producing and improving gas and diesel engines, most major automakers (original equipment manufacturers or OEMs — the main automotive brands) are phasing out new investments in internal combustion engines and announcing new and more ambitious targets in terms of electric vehicles sales and production. The market is reacting fast: since 2020, the uptake of electric vehicles in Europe has taken off at an unprecedented pace. Electric powertrains are no longer the preserve of small city cars or some luxury brands, and now equip the full range of segments. The electrification of "the machine that changed the world" (Womac, Jones, Roos, 1991) — which is currently providing work to some 14.6 million people in Europe (ACEA, 2021) — will lead to changes in the geographical distribution of industrial supply chain activities, the abilities and skills needed, and possibly the level of employment. After all, it takes more labour hours to assemble and build an internal combustion engine vehicle than an electric powertrain and this will have effects on employment (CLEPA/PwC, 2021).

Electrification can take different forms, as the family of electric and hybrid vehicles is composed of various categories:

- Pure electric models — battery electric vehicles (BEVs), like Tesla or the BMW i3.
- Plug-in hybrid electric vehicles (PHEVs) using both petrol and an electric powertrain can run on either or a combination of the two, while the battery is charged by connecting it to the mains.
- Hybrid electric vehicles (HEVs), like the Toyota Prius launched over two decades ago (in 1997), in which an internal combustion engine (ICE) is aided by an electric motor. Its battery is recharged via the internal combustion engine and regenerative braking.
- Fuel cell electric vehicles (FCEVs), or hydrogen vehicles, in which typically compressed liquid hydrogen reacts with air (oxygen) to power an electric motor.

Automakers are promoting hybrids, plug-ins and fully electric models as newcomers to the market (with the latter limited by the current low density of charging infrastructure). New EU legislation — especially Fit for 55, announced in July 2021 — accelerates the transition towards fully electric models, well before the key date of 2035 made explicit by EU authorities. Sales of battery electric vehicles, plug-in hybrids and hybrids reached 10% of total European sales in 2019, 24% in 2020 and 40% in 2021.

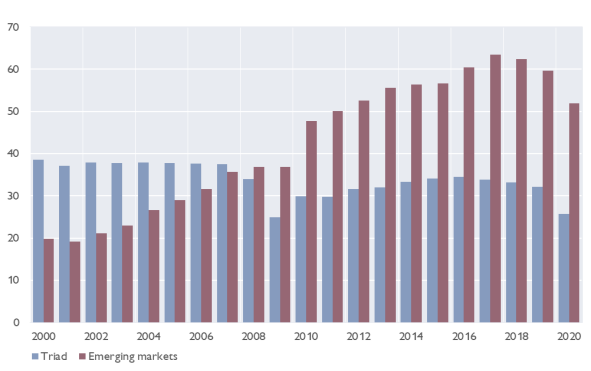
The radical transformation of the electric revolution comes in addition to numerous other structural changes on the demand and supply side. These shifts are driven by socioeconomic trends, new regulatory requirements and the adoption of emerging technologies, especially in vehicle automation and connectivity. On the one hand, cars are increasingly becoming a concentration of advanced technology, equipped with multiple high-tech comfort, entertainment and safety systems. In terms of hardware, the focus of car manufacturers and suppliers is therefore moving from the motor, transmission and chassis to alternative powertrains, batteries, smart sensors, semiconductors and interiors (Deloitte, 2017). Modern cars also provide major opportunities for software, with a key role played by connectivity, mobility and consumer data (such as maps, traffic information, assistant systems, device integration and over-the-air services), mobility analytics and artificial intelligence. A particular trend in the automotive industry is the development of autonomous driving. On the other hand, these technical advances come at a time of declining demand for cars on the back of socioeconomic trends such as the shared and greening economy, where car ownership is no longer

seen as a status symbol or the preferred mode of transport by an increasing number of people. Such a transformation require all industrial players to commit to high and inflexible investments on multiple technology fronts.

The last two decades have seen a shift in worldwide production hierarchies benefitting emerging markets (Cassia and Ferrazzi, 2018). Car manufacturing has traditionally been dominated by European, Japanese and US players, the so-called Triad. At the beginning of the 21st century, vehicle production in the Triad represented almost 70% of world production. 20 years later, this share was a mere 33%. Production in the Triad also declined in absolute terms: around 26 million vehicles were produced in 2020 (32 million in 2019) compared to 39 million in 2000 (see Chart 1). China alone is currently producing the same number of vehicles as the Triad (in 2000, the Triad produced 20 times the number of vehicles manufactured in China). The shift in production towards emerging markets (see Chart 2, Chart 3 and Chart 4) has been driven both by increasing local demand and the relocation of production choices by the main European, Japanese and US automakers.

Chart 1

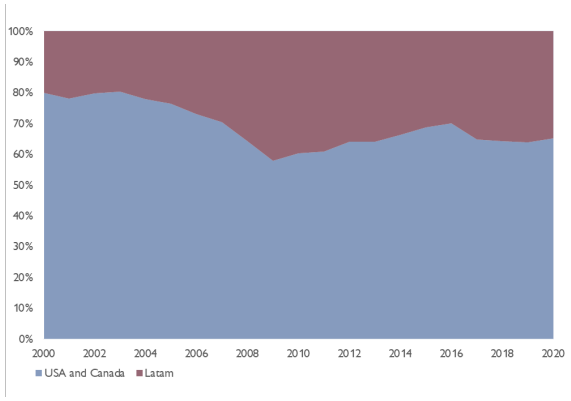
World production
(number of vehicles, million)



Source: OICA.

Chart 2

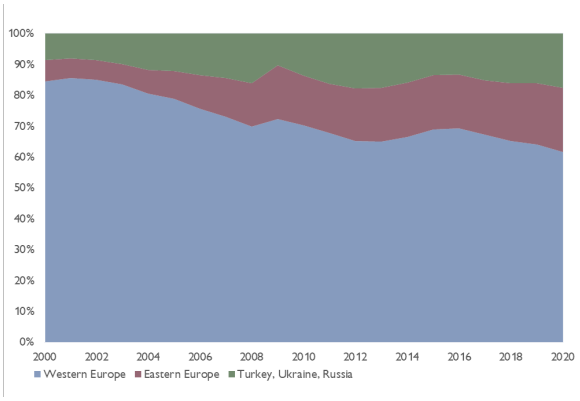
Production in America
(number of vehicles, % on total)



Source: OICA.

Chart 3

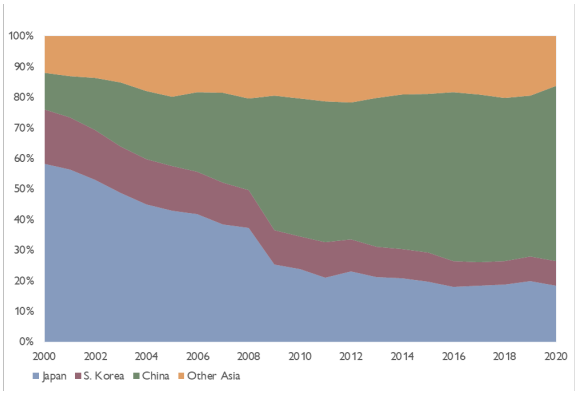
Production in Europe
(number of vehicles, % on total)



Source: OICA.

Chart 4

Production in Asia
(number of vehicles, % on total)



Source: OICA.

CESEE countries have benefited a great deal from the relocation of car production. The automotive industry in the region saw major investment and capital inflows, especially during the 2000s and up until the outbreak of the global financial crisis in 2008/9. Despite remaining a relatively small market in terms of sales of new cars, the region thus became a relevant production base for Western car manufacturers and suppliers (see Table 1). The global automotive sector is dominated by a small number of producers with huge volumes — the top ten world players account for more than 80% of production and sales. All top players have production sites in the CESEE region. Domestic value added content of car production in CESEE is still relatively low, however, reflecting specialisation in some lower value added segments of the value chain (Klein, Høj and Machlica, 2021).

Table 1

Production and sales in the world and in Europe

no. of vehicles (million)	World	Western Europe and UK	CESEE
Production (2019)	91.8	12.6	3.9 (24% of EU+UK)
Production (2020)	78.0	9.5	3.2 (25%)
Sales (2019)	90.4	16.1	1.7 (9% of EU+UK)
Sales (2020)	78.0	12.2	1.2 (9%)

Source: OICA, ACEA.

This paper will address the key questions of whether the automotive sector in CESEE is ready for the transition to electric vehicles and other current trends, and what the industrial and macrofinancial implications will be. The report is structured as follows: Chapter 1 discusses the main trends in the global automotive sector, focusing on the fast pace of the transition to electric vehicles. It takes into account short and long-term changes (particularly COVID-19, shared mobility, connectivity and autonomous vehicles) and focuses on two key elements: the essential role of battery production in Europe and the development of charging infrastructure. In Chapter 2, we turn our attention to the role of the automotive sector for CESEE countries in terms of production, foreign direct investment (FDI) and trade. We also explore automakers' investments in electric vehicle production in the region, considering their (evolving) plans and announcements. Moreover, we analyse aspects related to innovation activity and potential in CESEE relative to the rest of European Union (including R&D, patents and startups). In Chapter 3, we draw on the EIB Investment Survey to characterise the structural features, investment and investment finance of automotive firms in CESEE. Chapter 4 describes the risks, costs, opportunities and regulatory challenges related to the electric transition, and the bumpy road to a decarbonised economy.

Our analysis suggests that the CESEE region has the potential to remain an integral part of automotive production in Europe in the electric era, although this is subject to risks and costs. Its proximity to and close ties with Germany — the future hub of European electromobility — is a key determinant, prerequisite and thus policy priority for countries in the region. Predominant foreign ownership means that the local automotive industry depends largely on strategic decisions made in headquarter countries. As it stands, the transition to the production of electric cars may lag behind Western European countries due to a lower innovation capacity in CESEE countries and their focus on value chain functions with lower added value. Therefore, while the shift to electric vehicles takes place, part of the automobile industry in the region will stick to the outgoing internal combustion engine technology for longer, mainly to serve markets with a slower electric vehicle adoption (especially those outside the European Union). Although CESEE countries will remain at the core of the European

automotive industry, structural shifts are likely to change the status of various production sites and related supply chains, with battery production playing a particularly crucial role. Against this background, the automotive sector transition presents many challenges for CESEE countries, especially in terms of human capital, skills, innovation capacity, and also fiscal and monetary policy. Yet the structural shift also provides big opportunities to foster a more dynamic innovation ecosystem.

1 A sector in motion: Global trends and challenges

1.1 The pandemic and its implications for the automotive sector

The COVID-19 crisis has taken a heavy toll on the automobile industry. The sector was initially among the most affected by the economic crisis generated by the pandemic. During the first few weeks of lockdowns in the spring of 2020, cross-border movements were limited and the main concerns were related to the interruption of the automotive supply chain, which is among the deepest and most complex in the world. As expected, it was under strain for several months, with disruption to Chinese parts exports, large-scale manufacturing interruptions and the closure of assembly plants across Europe and in the United States. However, concerns soon shifted to the demand side. Many consumers postponed their car purchase, either because they could not visit car dealers or due to worries about the impact of the crisis on their purchasing power. As Table 2 suggests, overall car sales for 2020 collapsed by more than 20% in Europe, Latin America and Africa, and by between 10% and 20% in North America, in most Asian countries, and globally (-14%). China is an exception, as it remained one of the few resilient markets (with car sales falling by only 1.9% in 2020). Supply chain concerns resurfaced a few months later, this time mostly related to chip shortages.

Table 2

New vehicle registrations across the world (million vehicles)

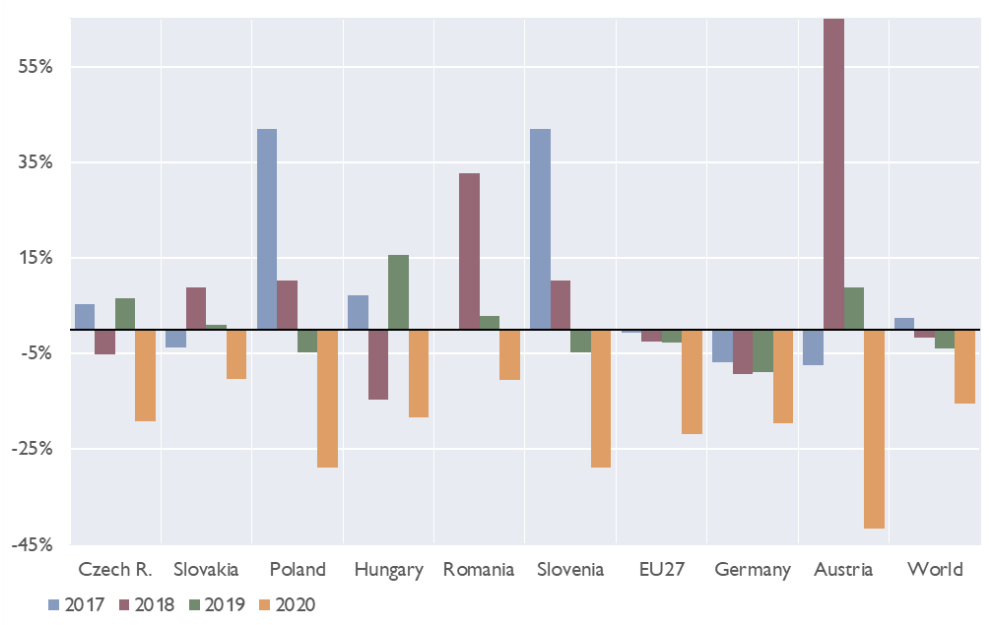
	2019	2020	% change
Europe	20.9	16.7	-20.2%
EU27, EFTA, UK	18.4	14.1	-23.6%
Russia, Turkey and other	2.5	2.6	5.1%
NAFTA	20.3	17.0	-16.6%
Latin America	4.5	3.3	-26.9%
Asia, Oceania and Middle East	43.5	40.1	-7.8%
China	25.8	25.3	-1.9%
Japan	5.2	4.6	-11.5%
Oceania	1.2	1.0	-14.8%
Middle East	1.1	0.9	-19.6%
Africa	1.2	0.9	-22.6%
World total	90.4	78.0	-13.8%

Source: ACEA.

Production declined during 2020 in line with weaker demand or — in many cases — even more sharply. Global production thus shrank by 15% in 2020, more than during the global financial crisis of 2009. Back then world production declined by 13% overall, but recovered in a few months to previous levels. In Europe, production reached its lowest level in two decades in 2020, declining by 23% (see Chart 5). While Western Europe saw production fall by almost a quarter compared to the previous year, CESEE countries (which are dependent on foreign demand, with the European market accounting for two-thirds of exports) experienced a more limited production decline (18%).

Chart 5

Growth rate in new vehicle registrations (% yearly change)



Source: ACEA.

The pandemic hit the automotive industry amid a cyclical slowdown that started in 2017, and came on top of massive structural changes on the demand and supply side. While these structural changes will be addressed in detail below, worldwide and European (particularly German[2]) car production had been stagnant or even contracting for several years before the pandemic hit. Moreover, the automotive sector had been subject to additional external factors such as a slowdown of the Chinese economy, further escalation of trade conflicts and Brexit[3].Nonetheless, CESEE countries had to a large extent defied these trends and navigated the challenges well.

Estimating the overall longer-term effects of the COVID-19 crisis on the automotive sector is a more complex exercise. This is due to factors including the pandemic's interaction with the other important structural trends discussed in the following chapters. Nonetheless, the COVID-19 crisis has brought about some new trends and forces that might have a longer-lasting impact:

- **Widespread teleworking may affect car demand** by reducing car usage, maintenance needs and purchases, and by extending vehicle lifetimes. Some demand may be shifted to car sharing or different modes of transportation (such as bikes or scooters). Conversely, reluctance to use public transportation due to social distancing may benefit car demand (Klein, Høj and Machlica, 2021).
- **Global supply chains, which suffered from interruptions and higher costs in the wake of the pandemic, may be shaped differently in the future.** In particular, more emphasis may be placed on security rather than on efficiency[4]. Disruptions to supply chains have not been

[2] The idiosyncratic development in Germany was primarily the result of weakened domestic demand and delivery delays caused by the introduction of new emissions standards (WLTP — Worldwide Harmonized Light Vehicle Test Procedure). Another factor rather specific to Germany was the ban on older diesel engine cars in cities, which added to the long-term downward trend in demand for diesel cars.

[3] According to some estimates, Brexit might knock off some 30% of German car sales in the United Kingdom (ING, 2019).

[4] For a broader discussion of exposure to shocks in global value chains and the consequences of a stylised re-localisation policy scenario, in terms of economic efficiency and stability, see OECD (2021).

limited to the immediate impact of the pandemic and lockdowns, extending to second round effects in the wake of demand and supply side shifts. One example is the shortage of semiconductors that started in late 2020 and looks set to last into 2022/2023. After the global financial crisis in 2008/9, global value chains did not fully recover to previous levels. In a similar vein, the pandemic could trigger a shortening of supply chains (the tendency to have suppliers closer to production sites), which has already been observed over the last decade (OECD, 2020). As a result, CESEE suppliers could benefit from stronger links with main automakers and the possible near-shoring tendencies. The literature presents survey-based early signs that some firms are already shifting production closer to consumers by near-shoring or re-shoring[5]. Culafic et al. (2021) argue that Western Balkan economies in particular could indeed benefit from near-shoring trends in the post-pandemic world if more focus is put on skilled labour, education and training as well as improvement of infrastructure and governance. In contrast, however, Altomonte et al. (2020) show that CESEE countries are mostly integrated into EU — rather than global — value chains. This means that their exposure to shocks from outside the European Union has been limited, even when controlling for their production structure. Yet this obviously does not quite apply to the global shortage of chips. The automotive industry and those EU-CESEE economies that specialise heavily in the sector — Slovakia, the Czech Republic, Hungary and Romania — have been particularly badly affected, with resulting economic losses of up to 1% of gross domestic product (GDP) in 2021 (see Hanzl-Weiss and Reiter, 2022).

- **The sector will be further digitalised**, not only in terms of industrial processes but also in terms of interaction of dealers with consumers.
- **Finally, government support programmes are playing a role, contributing to a significant acceleration of the electrification of the automotive sector.** Such programmes are widespread in most European countries and are part of unprecedented economic stimulus triggered by the COVID-19 crisis (Klein, Høj and Machlica, 2021), together with the EU recovery plan (see Box 4 in Chapter 3). In this sense, the public sector is playing a more relevant role in guiding consumers' choices than before, and the car industry is among the sectors receiving government support on the road to a greener economy.

[5] See, for example, Culafic et al. (2021) or Saurav (2020).

1.2 A number of profound and structural changes

The global automotive industry is undergoing a fundamental transformation process driven by autonomous driving, shared mobility, connectivity and electrification[6]. As electrification is dominating the headlines, we will elaborate on it in the next section.

Electrification aside, a number of structural changes will not only deeply affect the automotive industry but probably also bring about new mobility concepts in a broader sense over the coming years (Cassia and Ferrazzi, 2018):

- **Autonomous vehicles**: The self-driving car is among the automotive industry's most fascinating innovations. In the meantime, automotive players are working on providing incremental automation capabilities. The spread of automation technologies will gradually increase along the scale from Level 1 to Level 5[7]. Autonomous driving can relieve drivers of some everyday tasks, especially in congested areas or for long-distance situations: the car can perform many tasks automatically, but the driver remains in control, at the wheel. Self-driving cars — for which tests on the streets of California started more than a decade ago — will instead not require any human intervention and do not even have a steering wheel. Many major automakers are cooperating on such topics with tech giants (FCA with Google, Volkswagen with LG, BMW with Intel, Mercedes with Bosch, etc.) and investing directly. Tier 1 suppliers are also doing so, playing the role of system integrators. While regulatory and legal issues are the main obstacles to the market roll-out of driverless cars (Pattison et al., 2020), consumer acceptance can also play a role. Substantial technology investments are also still needed. Another new, so far broadly unexplored, area of transport is urban air mobility — a means of transporting goods and passengers by air in urban environments using electric aircraft that take off and land vertically, with or without a pilot on board. Initial operations are expected to take place within three to five years and some traditional car manufacturers like Hyundai aim to secure leadership in this high-potential market. Development will, however, crucially depend on consumer acceptance, which has so far been rather mixed (EASA, 2021).
- **Shared mobility**: Car ownership has become less popular and attractive than in the past for several reasons. Firstly, car ownership costs are increasing — this applies not only to direct financial costs but also to hidden costs, for example increasingly congested roads and a shortage of parking spaces (particularly in urban areas)[8], while regulatory disincentives for using (or owning) cars in city centres discourage people from having a car. Secondly, younger generations no longer see a car as a status symbol. As a result, vehicle sharing and co-modal mobility (which is not only car-dominated) is increasingly common, and is being helped by rising environmental awareness about carbon footprints, alternative means of transport (including (e-)bikes, (e-)scooters, etc.) and technological advances. The boom in car sharing that started in the 2010s has been largely driven by the free-floating model favoured by advances in communication and positioning technologies (such as GPS or the EU Galileo) and

[6] Daimler has coined the acronym CASE for this process. PWC (2018) put the terms in a different order and added "Yearly update" so that they refer to the car of the future as EASCY.

[7] Level 1 ("feet off") = driver assistance like, for example, adaptive cruise control; Level 2 ("hands off") = partial automation: the car maintains speed, slows down, stays in lane; Level 3 ("eyes off") = conditional automation: cars can take some decisions like changing lanes, or breaking or overcoming other vehicles, but the driver must stay ready as a back-up; Level 4 ("brain off") = high automation: the car can handle most of the situations by itself; Level 5 = driverless, with no pedal, no steering wheel and no human intervention of any kind. Level 1 and Level 2 features are available in some vehicles already sold on the market, while Level 3, Level 4 and Level 5 features are at the level of prototypes.

[8] European cities are particularly ill-suited for car-based mobility. Traffic and parking-related costs make up about 45% of the total cost of ownership in the United States and about 54% in Germany (Inrix, 2018).

enabled by digital platforms. The model expects the user to take a car and use it for a short period of time, without the need to return it to a specific parking place. Many automotive brands are entering the car-sharing market, including Mercedes and BMW with Sharenow, for instance. Uber, which connects passengers with drivers (in most countries, depending on local regulations, these are self-employed professionals), has created a service similar to a taxi, changing the shape of mobility in the cities where it operates. The company has more than 90 million monthly active users. Services similar to Uber are provided by other platforms (Bolt, Cabify, Lyft, Gett — which has Volkswagen as an investor — etc.). Other peer-to-peer schemes, like the French BlaBlaCar — a car-pooling community of more than 100 million users who share trips and travel expenses (drivers are not professionals, and both drivers and passengers are rated via the platform) — are increasingly popular. In the near future, robo-taxis (self-driving taxis operated by a ride-sharing company) will be a major mobility solution, potentially affecting demand for cars, as more availability of shared vehicles may reduce the demand for new cars (Shaheen, Cohen, 2013) at least in the big cities of developed countries. The trend towards shared mobility also implies a shift to more usage-based mobility services. Fleet operators providing such services are thus expected to replace private individual as major automakers' main customers in the future (Deloitte, 2020).

- **Connectivity**: Technological and digital advances are another factor redefining mobility. Rapid developments in electronics, software and (big) data processing are increasingly transforming the car from a primarily mobility product into a computer on wheels, or rather a connected data processing platform. There are currently around 1 400 chips in a typical vehicle[9], and cars rely on chips for everything from electric windows to driver-assistance systems. Increasingly connected cars provide new business opportunities for major automakers, ranging from value added services such as over-the-air software updates and packages to valuable and marketable user and vehicle data. Connected cars provide a significant edge in sales potential. According to Deloitte (2017), automakers' mobility and data management may account for about 20% of revenues in 2025 while the revenue share of vehicle sales — the traditional automaker business — will drop from 75% in 2015 to about 60% in 2025. However, on the flipside these opportunities will require to adapt their business models accordingly. Traditional car producers are engaging in increasing levels of cooperation with high-tech and IT companies. The higher the value that these partner companies add to the vehicle, the higher the risk of a relative power shift away from traditional automakers.

- **New automotive players entering the arena**: The large majority of top Western automakers were established 100-120 years ago and dominated the sector in the last century. However, the above-mentioned changes may shake up the competitive arena, with the leaders in self-driving technologies, electromobility and connectivity as potential winners. Tesla is a good example: taking advantage of the electrification trend, the Palo Alto, California-based company released its first car in 2008 and was able to sell 500 000 vehicles in 2020 and almost 1 million in 2021, selling fully electric vehicles exclusively since it was formed. The company surpassed a stock market capitalisation of USD 1 trillion in 2021 (more than six times the market capitalisation of General Motors and Ford combined). Google entered the sector with Waymo — the Google car — which is currently operating a driverless taxi service in Arizona and is providing its autonomous driving technologies for other vehicles. Apple continues to eye key entry opportunities into the sector, hire engineers to develop self-driving electric

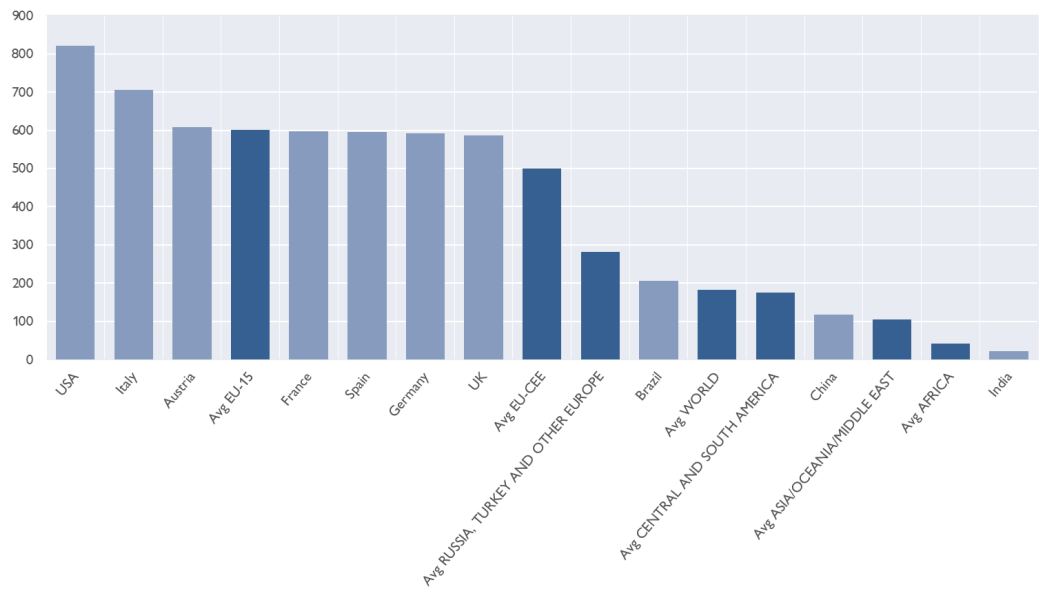
[9] Synergies in software development | audi.com

vehicles and establish cooperation with top automakers. The Apple car may be launched in the next five years, with efficient battery and sensor technology and especially effective assisted-driving capabilities, unless the company chooses to license its self-driving technology to third-party manufacturers. Sony has also launched an electric vehicle unit to explore entering the automotive market. Electric vehicle technology — simpler and with lower legacy and sunk costs — is lowering the traditional barriers to entry of the automotive industry. Chinese players, gaining in scale and relevance, may also enter new markets outside China. And in the future, new players may arrive from the suppliers' arena, especially those managing the most advanced technologies connected to some of the vehicles' most important features (cockpit, advanced driver-assistance systems or ADAS).

- **Saturation of the Western market**: The saturation of wealthier markets (and the related overcapacity of the respective factories, which have been operating at far from full capacity for decades) is not a new phenomenon, but it has evolved over time. The motorisation rate is particularly high in Europe and Japan (with 600 vehicles in circulation per 1 000 people) and even higher in the United States (with 800 vehicles per 1 000 people — see Chart 6). These values are particularly high considering that a significant part of the population (minors and the elderly) does not drive. At a global level, the saturation of the car market is by far lower, with 200 cars per 1 000 people. On the one hand, the wealthiest markets are partially saturated; on the other hand, there are many potential new consumers — especially the middle class in developing and emerging markets — that may buy a car whenever they can afford it (the motorisation rate increases sharply when the average income of the country surpasses USD 20 000 per year — Cassia and Ferrazzi, 2018). The number of cars in circulation is a source of concern: around 1.5 billion cars are in use globally, increasing yearly by an additional 50 million (the number of new cars sold on the global market minus those that are scrapped — see Chart 7). If current trends continue, our calculations indicate that the world would have more than 5.5 billion cars in 2050, which is clearly unsustainable from an environmental point of view (not only for CO_2 emissions and pollution, but also in terms of negative external factors generated by private mobility, the use of public space, materials, etc.).

Chart 6

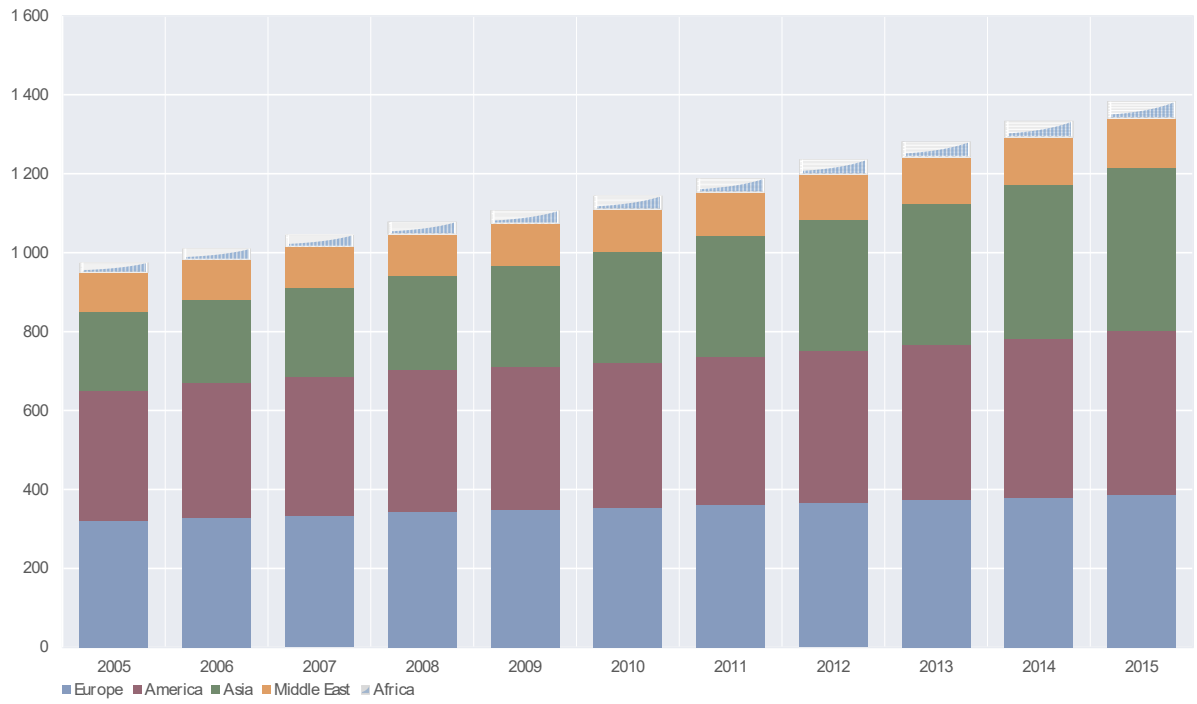
Motorisation rate (vehicles per 1 000 people, 2015)



Source: ACEA.

Chart 7

World vehicle in use (millions, 2015)



Source: ACEA.

These long-term structural trends also present major opportunities, not only for car producers and their suppliers but also for economies more broadly. For instance, the adoption of electric vehicles may represent an opportunity for renewal, with demand in the most mature markets previously driven mostly by (slow) substitution. However, the structural overhaul of the industry also implies equally substantial challenges subject to serious risks that could eventually dent demand for cars and car parts produced in Europe in general — and in the CESEE region in particular — with multiplying effects throughout their economies. We will elaborate on some of these risks in Chapter 4.

1.3 The green transition and electric vehicles

Among the most important structural changes faced by the automotive industry are related to the global fight against climate change and the need to reduce emissions. When the Paris Agreement[10] was signed in 2015, only a handful of automakers had set clear goals for reducing greenhouse gas emissions. More recently, all major players in the automotive industry have scaled up their efforts to decarbonise. Most major carmakers have announced specific targets and timelines regarding the reduction of greenhouse gas emissions[11]. These plans encompass the downstream and upstream value chain, the automakers' manufacturing operations and the greening of their vehicle portfolios.

CO_2 emissions and sales bans of new internal combustion engine vehicles are in the sights of regulatory authorities. Most attention has been paid to the vehicle portfolio. The transport sector accounts for almost a quarter of global CO_2 emissions. Passenger road vehicles account for 45% of transport emissions, while 30% is coming from road freight vehicle transport (12% from aviation, 11% from shipping), according to the International Energy Agency (IEA). CO_2 emission standards set for passenger cars by the respective authorities have been tightened since 2000. The emission standards refer to tailpipe emissions only (those allowed in the exhaust gases of a car). The corollary of such a definition is that electric vehicles are carbon-neutral since their overall CO_2 balance measured over their entire life cycle is not taken into account[12]. A growing number of public authorities worldwide have therefore set deadlines for banning the sale or registration of new internal combustion engine vehicles. European countries are rather ambitious not only when it comes to the target term (Norway will require all new passenger and light commercial vehicles to have zero tailpipe emissions from as early as 2025, for instance), but also with respect to which types of cars will be banned. As Chart 8 shows, in addition to internal combustion engine vehicles, most European countries will extend the ban to plug-in hybrids.

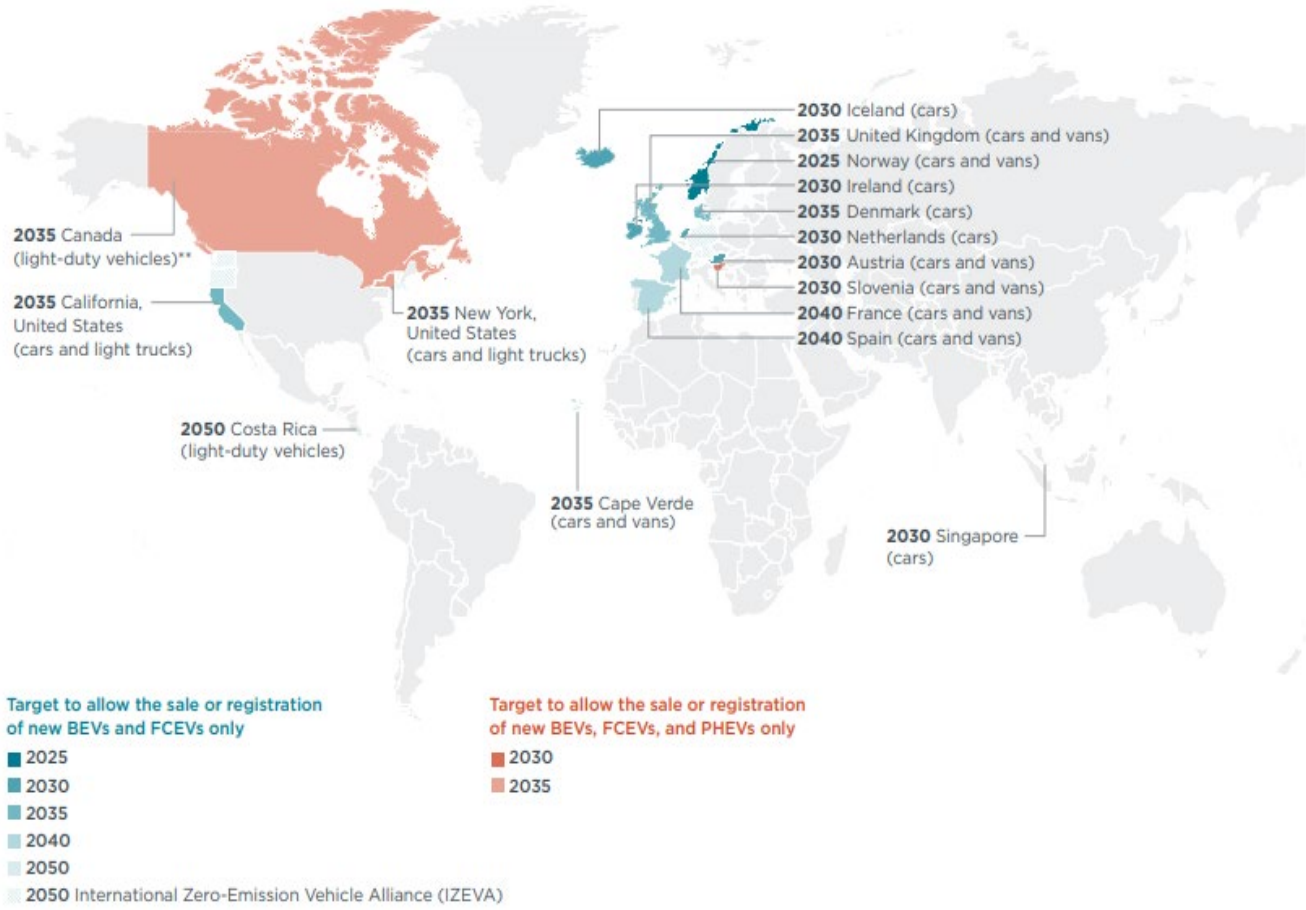
[10] The first-ever universal, legally binding international treaty on climate change adopted by 196 countries with the aim to limit global warming to well below 2, preferably to 1.5 °C, compared to pre-industrial levels.

[11] Emissions are divided into Scope 1 emissions (those released on the firm site, for instance during industrial processes), Scope 2 (which are indirect, created by the generation of purchased electricity or heat needed by the firm) and Scope 3 (indirect emissions that occur in the value chain of a company or generated by the product sold, for instance as a result of the vehicles operating in customers' hands). Scope 3 emissions are particularly relevant for the automotive industry.

[12] A more detailed discussion of the CO_2 balance of electric vehicles is provided in Chapter.

Chart 8

Governments' target dates for a 100% phase-out of sales/registrations of new internal combustion engine cars (as of September 2021)



* Includes countries, states, and provinces that have set targets to only allow the sale or registration of new battery electric vehicles (BEVs), fuel cell electric vehicles (FCEVs), and plug-in hybrid electric vehicles (PHEVs). Countries such as Japan with pledges that include hybrid electric vehicles (HEVs) and mild hybrid electric vehicles (MHEVs) are excluded as these vehicles are non plug-in hybrids.
** The Canadian province of British Columbia has set its 2040 target into binding regulation; the Canadian province of Québec has also set a target for 2035.

Source: International Council on Clean Transportation (ICCT).

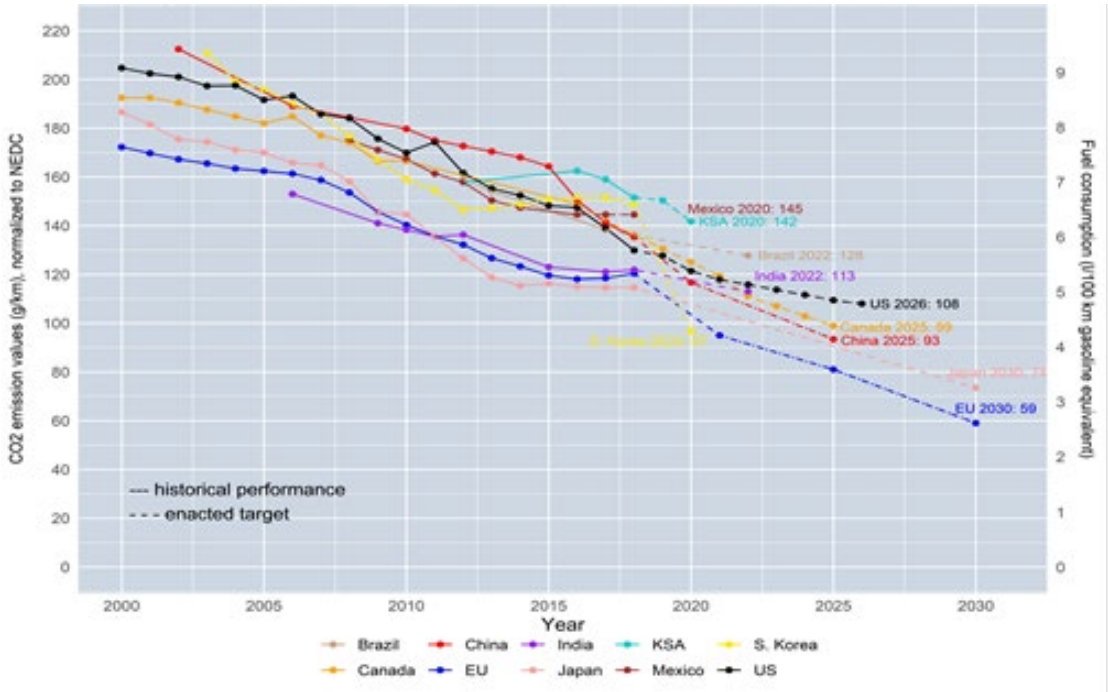
However, the European Union's ambitious emission standards (which are not limited to CO_2) and mounting peer and market pressure imply a de facto ban on internal combustion engine vehicles that will apply from significantly sooner. According to a European Commission proposal in the Fit for 55 package announced on 14 July 2021, CO_2 emissions from cars would have to be cut by 55% compared to 2021 levels by 2030 (much higher than the previous reduction target of 37.5%) and by 100% by 2035. Such a proposal, which is still subject to the approval of Member States and the European Parliament, amounts to a de facto ban on the sale of new internal combustion engine cars — but also plug-in hybrid and hybrid models — from 2035 ("all new cars registered as of 2035 will be zero-emission" according to Fit for 55 proposal). However, new internal combustion engine vehicles might be implicitly disqualified from the market earlier. This is because the set CO_2 targets require average petrol consumption per 100 km (see right axis in Chart 9) that will soon be technically infeasible without the employment of electric vehicles, despite the continuously increasing efficiency of combustion engines[13]. Moreover, in addition to CO_2 emission standards, the European Commission

[13] The average fuel consumption of petrol and diesel cars in the European Union declined by about 1.2 and 1.7 l/100 km, respectively, between 1990 and 2015 (Gonzalez et al., 2019).

has also been setting standards for exhaust emissions to curb pollution from vehicles since 1993. This norm is known as Euro 1 to Euro 6, with the latter entering into force in 2015. The EU Commission is currently working on Euro 7 standards. While the details are still a work in progress, the automotive industry warns that the norm might be technically impossible to achieve for internal combustion engine vehicles. If that concern turned out to be correct, Euro 7 would amount to a de facto back-door ban on these vehicles in the European Union from 2025 on, when the regulation is supposed to come into force. On top of the regulations concerning the automotive sector directly, a number of other regulations are indirectly affecting the sector. For instance, the EU taxonomy or the financial sector regulation (on environmental, social and governance disclosure, or climate risk) will also be an important accelerator of the shift to electric vehicles as banks and insurance companies are provided with strong incentives to support green activities including electric vehicles. Finally, the ever-stricter regulation comes at a time of mounting public, peer and market pressure accelerating car electrification.

Chart 9

Passenger car CO_2 emission and fuel consumption values (normalised to New European Driving Cycle[14])



Source: International Council on Clean Transportation (ICCT, updated May 2020).

[14] New European Driving Cycle (NEDC) is a version of the former ECE+EUDC test, which was used for emission certification of light duty vehicles in Europe.

As a result, all major traditional automakers have not only announced an explicit time schedule for the transition, but are also continuing to rush towards more ambitious electrification targets. All major automakers significantly accelerated their shift towards electrification during 2021, announcing a series of new investments mainly dedicated to the electric transition for the next few years. Toyota[15] announced investments in electric of USD 35 billion, Volkswagen, Stellantis, Ford and BMW of USD 30 billion each, General Motors of USD 27 billion, Nissan of USD 17 billion and Daimler of EUR 70 billion in the next five to ten years. The rush towards new and more ambitious electrification targets has been intensifying in recent months. For example, according to company announcements, all Jaguar luxury cars, 50% of BMW vehicles and 40% of Ford vehicles will be fully electric by 2030, while 30% of Renault vehicles will already be electric by 2025. Other players are announcing targets including both fully electric and hybrid models (Toyota: 50% before 2030; Stellantis: 70% of European sales, of which 80% are pure electric models) before 2030; Daimler: 15-25% by 2025). Other players are envisaging specific dates for a fully electrified line-up (General Motors is planning to do this by 2040). Ambitious electrification goals have become a crucial marketing instrument for major automakers. Frequent media and press announcements teem with updates and further honing of electrification strategies. Nonetheless, their electrification policies and goals are relatively difficult to compare, due to differing definitions of electric (which is sometimes narrow — battery electric, plug-in hybrid and fuel cell — and in other cases includes hybrid solutions), differing time horizons and differing strategies between brands within each group. However, the particularly ambitious electrification goals seem to have more distant time horizons (2035-2040), which reflects the complexity and capital-intensive nature of this massive structural shift. In contrast to their long-term plans, car manufacturers' electric vehicle sales projections for the short to medium term tend to not only be more conservative, but also to encompass (explicitly or implicitly) any vehicles with an electric motor, including hybrid models (this applies to Toyota, Renault, Daimler and Skoda) and plug-in hybrids. In general, high-volume brands prioritise battery electric vehicles (Fitch Solutions, 2021) and longer timelines in the electrification race, as this allows for more time to take advantage of economies of scale, consolidate platforms and vertically integrate electric vehicle battery manufacturing into increasingly regionalised supply chains. The purposeful use of vague electrification terms grants automakers some flexibility to continue selling partial internal combustion engine vehicles (hybrids and plug-in hybrids) in the markets (particularly emerging markets) that will not restrict them for the foreseeable future.

The European market is in the lead on electrification. Owing mainly to the policymaking of the European Commission and individual European countries, major automakers' electrification targets are typically more ambitious in Europe than in other areas where electrification is also advancing quickly (such as China and the United States). For instance, whereas Volkswagen wants battery electrics to account for 70% of sales in 2030 in Europe, a figure of "only" 50% is envisaged for the United States and China. Nissan wants 75% of its European sales to be electric by 2026 and 40% in the United States by 2030. Ford will offer only electric and plug-in hybrid models in Europe by 2026, and by 2030 all of its passenger cars are set to run on batteries only, while at a global level Ford expects only 40% of its vehicles to be electric. PSA-Stellantis aims for 70% of its European and only 40% of its US sales to be battery electric or plug-in hybrid by 2030. Honda even projects all mainstream models sold in Europe to have an electrified powertrain by as early as 2022 (see Table 3).

[15] Toyota management has been in favour of a mix of hybrids, electric vehicles and hydrogen-powered vehicles instead of focusing only on battery-powered cars. But the efforts have gradually been changing: "I wasn't interested in Toyota's EVs until now. But now I'm interested in future EVs," said Toyota president Akio Toyoda in December 2021.

Table 3

Major automakers' electric vehicle targets

	2025	2030	2040
EV target		**TOYOTA** 5.5mn ECV units (aprox. 50% of total sales) annualy, out of which 3.5 mn BEV	
	SKODA ECV 25% of total global sales, further EV expansion depending on demand development	**VW** BEV > 70% of European sales (target doubled in 3/2021), 50% in US and China	
	DAIMLER Up to 50% of total unit sales BEV and PHEV, depending on demand and infrastructure	**DAIMLER** All electric, where market conditions allow	
	AUDI About a million ECV/year (40% of global sales)	**AUDI** Purely electric car maker	
		GM Fully electric, end of ICE production in 2035	
		FORD Targets all electric share of 40% to global volume with all-electric European lineup	
	HYUNDAI-KIA GROUP 1mn EV units/year of which 0.6 mn BEV	**KIA** By 2030, electric and hybrid vehicles are to account for 40% of the brand's total sales (annual sales target of 1.6mn units of which over 55% BEV).	
		STELLANTIS GROUP FCA and PSA to increase share of electrified cars to 70% in Europe. Additional PSA target of 40% of US sales.	
	NISSAN 70% of European car sales electric by 2026	**NISSAN** 40% of car sales in the USA electric	
	RENAULT 30% of sales from fully electric cars by 2025, with another 35% from hybrid models	**RENAULT** EVs will account for 90% of models	
		HONDA EV and FCV share of 40% of sales in major markets	**HONDA** EV and FCV share of 100% of all sales
	BMW BEV covering 90% of market segments from 2023. 2025 25% minimum share of electrified cars in total deliveries	**BMW** Fully electric sales to be 50% by 2030. MINI brand to be fully electric	
	JAGUAR-LAND ROVER Jaguar to become a full electric car brand by 2025	**JAGUAR-LAND ROVER** 60% of Land Rover luxury SUVs, to run solely on batteries by 2030	

Source: Company announcements.

Yet there will still be a role for traditional internal combustion engine vehicles and hybrid models. Some automakers see (partial) internal combustion engine vehicles only as an interim solution before the ultimate breakthrough of full electric vehicles in developed and — with a delay — emerging markets. Various companies have explicitly or tacitly voiced that internal combustion engine vehicles will continue to play a role in their plans — in emerging and developed countries — at least in the short term. Unlike the above-mentioned electrification frontrunners, a large group of car manufacturers seem to have made the supply of electric vehicles dependent on developments in demand. In an interview for a Czech newspaper in March 2021, Skoda board member Martin Jahn said, "Skoda will not be a brand that will switch to electric models only extremely quickly, because it is also strong in markets where the onset of electromobility will be a bit slower than in Western Europe and America. For a relatively long time, we will have a combination of electric and internal combustion engines. If we see that the market is moving towards even more intensive electrification, we can expand the offer of electric cars. (...) Electric cars sell well in countries where there is financial support for the purchase or where there are reliefs (...). We will see how the market develops when these special benefits end." Even Volkswagen — among the automakers with the greatest investment plans and ambitions in terms of electrification — concedes that its internal combustion engine fleet will be developed further, to be as efficient as possible and with a focus on hybrids.

Many major automakers see alternatives such as fuel cell technology as very promising. One significant fault line relates to the companies' stance towards battery-powered (battery electric and plug-in hybrid) vs. hydrogen-powered electric vehicles (fuel cells). Volkswagen Group seems to be the only major automaker to have strictly rejected hydrogen technology[16], with all other traditional big car manufacturers planning to rely on (and develop) fuel cell technology for the long-term future or for specific segments (typically for vehicles used for long-distance journeys, like trucks or buses) and to some extent (such as in light commercial or industrial vehicles). At the opposite end of the spectrum to Volkswagen are the major Japanese carmakers such as Toyota and the Korean Hyundai-Kia, which have been long-term advocates of fuel cell technology and have ambitious plans for the future. Several other companies (Renault, Ford, Daimler, BMW, Nissan and Jaguar Land Rover) are also working on a hydrogen model. Hydrogen-powered cars are still very costly, lack an appropriate supply chain and do not yet benefit from economies of scale. This means that they currently only serve a niche market of a few thousands consumers fascinated by the idea of emitting only water vapour. Only 11 000 hydrogen-powered cars are in use worldwide. A wider roll-out has been obstructed by a lack of infrastructure together with high costs and inefficiencies in the production of hydrogen. Another avenue explored by some players in the automotive industry (such as Bosch) are e-fuels (electrofuels, synthetic fuels), where (preferably renewable) electricity is used to split water into hydrogen and oxygen. The former is then combined with carbon dioxide to make drop-in hydrocarbons like diesel or gas, enabling e-fuels to be produced with a low carbon footprint. Their most appealing advantage is that existing internal combustion engine technology and infrastructure could be used, while achieving a significant CO_2 reduction. However, the production of e-fuels is currently still uneconomical. As a result, while the European automotive industry argues in favour of an open technological race to achieve CO_2 reduction objectives, it seems that for now this race has been won by electric vehicles and that not even e-fuels can save the internal combustion engine[17].

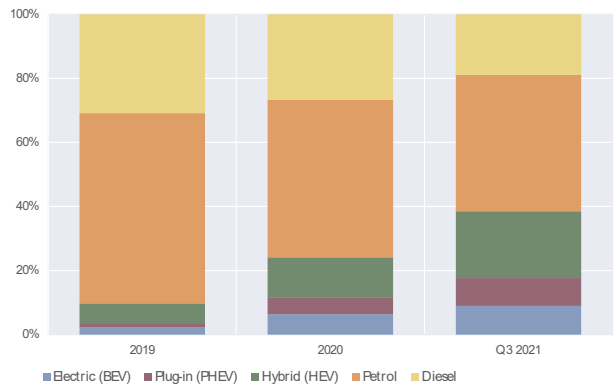
With major automakers stepping up their supply of electric vehicles, consumer adoption has been gathering pace. The pandemic-defying spike in electric vehicle registrations was brought about by additional public incentives, a growing number of electric vehicle models on the market and falling battery costs. While there were only 17 000 electric cars in circulation worldwide in 2010, by 2019 that number had increased to 7.2 million, 47% of which were in China and 24% in Europe (Garcia et al., 2020). 2020 and 2021 saw a significant boost in electric vehicle sales.

The electric vehicle boom has been driven by sales growth in Europe and China, with slight declines observed in North America. The European Union — which has overtaken China as the world's largest electric vehicle market — saw sales volumes of pure electric and plug-in hybrid vehicles reach 1.36 million units in 2020 (12% of total sales), with battery electrics accounting for slightly more than half of this. 1.5 million hybrid vehicles were also sold. Sales of petrol and diesel cars declined by more than 35%, while hybrid vehicles and battery electrics almost doubled. This electrification of sales continued in 2021: almost 40% of new car sales were battery electrics, plug-in hybrids or hybrids (with 18% covered by battery electric and plug-in hybrid vehicles), up from a mere 10% in 2019 (see Chart 10 and Chart 11).

[16] Herbert Diess, the chairman of Volkswagen's management board, expressed his skepticism bluntly: "You won't see any hydrogen usage in cars. (...) Not even in ten years, because the physics behind it are so unreasonable." Car groups throw spanner in works of EU's hydrogen drive | Financial Times (ft.com)

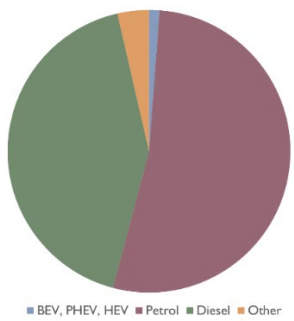
[17] E-fuels won't save the internal combustion engine - International Council on Clean Transportation (theicct.org)

Chart 10	Chart 11
Car registrations in Europe by fuel type	**Vehicles in use in the European Union by fuel type (2019)**



Note: Europe: EU+UK+EFTA. Excluding alternative vehicles (accounting for 1.6%).

Source: ACEA



Note: Data as of 2019.

Source: ACEA.

Even the most optimistic electric vehicle sales targets from automakers might not be sufficient to achieve carbon neutrality by 2070, and even less so by 2050. The automakers' overall electric vehicle plans translate into estimated global cumulative sales of electric passenger cars and light commercial vehicles of 55-73 million by 2025, according to IEA forecasts (2021a). The upper end of this range broadly corresponds to the trajectories of IEA's Sustainable Development Scenario (SDS), according to which net-zero emissions worldwide will be reached by 2070 and global temperature rises will stay below 1.7-1.8°C with a 66% probability, in line with the higher end of the Paris Agreement's temperature ambitions. The IEA's SDS projects that the number of electric light duty vehicles worldwide will rise from about 11 million in 2020 to about 66 million in 2025 and some 230 million in 2030. A more conservative baseline scenario[18] forecasts an increase to about 140 million in 2030. The IEA thus projects the sales share of electric vehicles to go up from about 5% globally (10% in Europe) in 2020 to 17-36% in 2030 (36-78% in Europe[19]), depending on the scenario. However, in another publication, the IEA estimates that for net carbon neutrality to be reached by 2050, the number of electric vehicles worldwide would have to rise to 350 million in 2030 (50% of sales in emerging and developing markets and 75% in developed markets) and 2 billion in 2050 (IEA 2021b). The discrepancy between even the most optimistic electric vehicle sales projections on the one hand and climate neutrality-compatible electric vehicle sales needs on the other are also corroborated by Transport & Environment (2021), Europe's leading clean transport campaign group. The organisation concludes that even in the best-case scenario (with carmakers delivering on production plans and voluntary commitments), estimated battery electric vehicle sales in the European Union would be around 57% in 2030, still 10 percentage points short of a Green Deal-compliant trajectory that requires battery electrics to account for no less than 67% of sales by then.

[18] This scenario reflects all existing policies, policy ambitions and targets that have been legislated for or announced by governments around the world. It includes current electric vehicle-related policies and regulations, as well as the expected effects of announced deployments and plans from industry stakeholders (IEA, 2021).

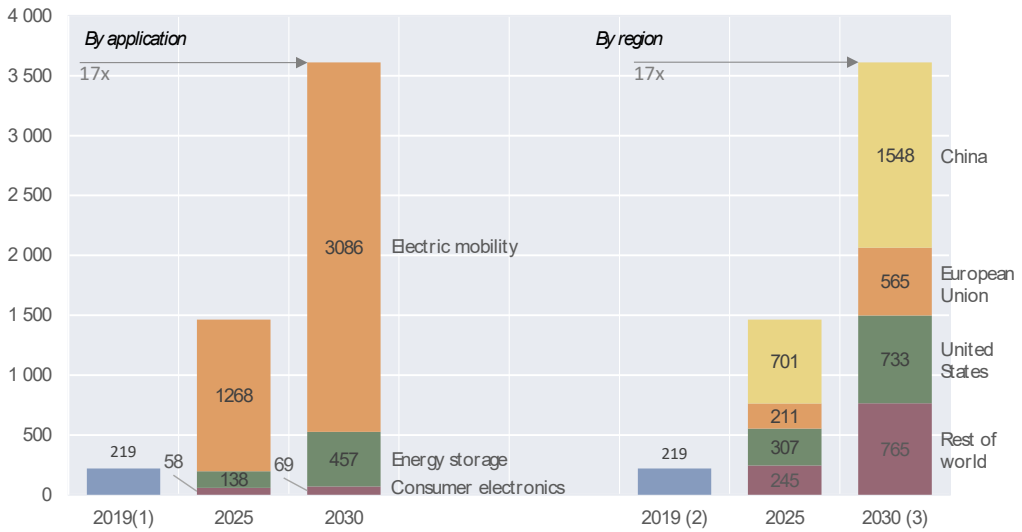
[19] These forecasts were developed before the presentation of the European Union's new climate policy proposal on 14 July 2021. This proposal scales up electrification ambitions significantly.

1.4 Battery manufacturing and battery technology development

The development of battery technology and its manufacturing capacity will play a prominent role in the transformation of the automotive sector. Lithium-ion (Li-ion) batteries (and future technology evolutions) — for which the current key end markets are portable devices and stationary/grid energy storage — are set to become most prominently used in electric vehicles. The transformation of the automotive industry and the resulting expected significant increase of demand for electric vehicles are the main drivers of future battery demand. They are also behind the major investments that are taking place (including in Europe) for the setup of new production capacity. Initiatives like the European Battery Alliance — which is supported by the European Commission and the European Investment Bank and brings together EU national authorities, regions, industry research institutes and other stakeholders — aim to develop an innovative, competitive and sustainable battery value chain in Europe. Tightening carbon regulations and the expected growth in adoption of electric vehicles are already driving increased demand and production capacity for Li-ion batteries. Because of their weight and importance in the assembly of electric vehicles, it is reasonable to expect that the production of Li-ion batteries will be progressively moved close to the regions where these vehicles will be assembled, a pattern already seen in Europe. In 2019, global demand for Li-ion batteries reached 219 GWh, with demand for electric vehicle batteries accounting for around 171 GWh (78% of the total) and clearly outgrowing demand from the consumer electronics market (40 GWh). Total demand is forecast to increase to more than 1 450 GWh by 2025 and over 3 600 GWh by 2030, with demand from the electric vehicle market accounting for over 85% of the total (see Chart 12). Europe alone is projected to see demand increase from 24 GWh in 2019 to 211 GWh by 2025 and 565 GWh by 2030[20] (a compound annual growth rate (CAGR) of about 33% in the period 2019-2030).

Chart 12

Global battery demand (GWh) forecasts



(1) of which 171 GWh for electric mobility; (2) of which 24 GWh for the European Union; (3) figures do not sum to total because of rounding.

Source: McKinsey analysis (2020) based on Global Battery Alliance and World Economic Forum data.

[20] McKinsey analysis based on Global Battery Alliance and World Economic Forum data.

Production capacity setup is rapidly following vast demand expansion. Gigafactory[21] capacity is being deployed rapidly and is forecast to continue expanding in the future, as it will be needed to meet growing market demand. As a result of the strong outlook for Li-ion battery demand, in particular from the electric vehicle segment, there has been significant investment in new battery cell and pack manufacturing capacity in recent years (60% CAGR from 2016 to 2020), with the majority of new capacity being added in China, which currently accounts for about three-quarters of total Li-ion battery capacity. Europe and the United States follow as significant producers.

Capacity announcements in Europe have ramped up since 2019, though many have not been implemented yet. With this in mind, total installed capacity for Li-ion cell batteries in Europe is projected to easily reach a level between 400 and 600 GWh by 2030 and 1000-1400 GWh in 2040. Further to McKinsey's 2020 forecasts — consistent with the expected evolution in demand — most recent forecasts[22] expect an acceleration in installed capacity for battery cells in Europe, potentially reaching 1 000 GWh by 2030 based on the announcements made. This could therefore point to an emerging risk of cell production overcapacity, though not all projects announced will be implemented, as most newcomers have yet to secure major automaker customers and are at disadvantage compared to the established cell suppliers. Depending on the average production capacity of one gigafactory[23], roughly 20 such production sites will be necessary in Europe in 2030 and about 35 in 2040 to cover battery demand (Deloitte, 2021). According to some sector consultants[24], the average size of such gigafactories is also growing along with total installed capacity: it was about 7.3 GWh in 2020 and is expected to range somewhere between 20 and 30 GWh by 2030. It is largely expected that battery cell technology innovation and cost reduction and the deployment of battery manufacturing capacity will make wider adoption of electric vehicles possible.

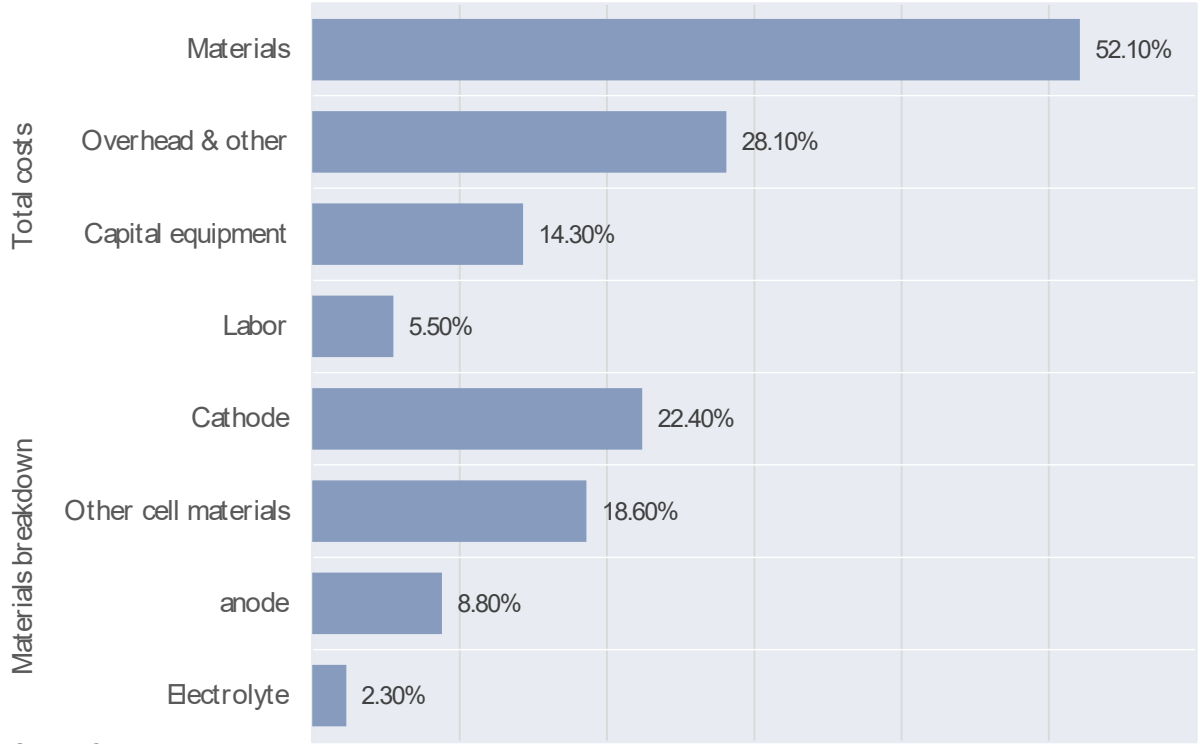
Batteries are set to become the most important component of electric vehicles. The battery pack and its associated electronics and software systems will be main determining factor of the performance of the vehicle and will identify and differentiate it from its competitors. In a sense, they are likely to become what internal combustion engines were for traditional vehicles. Battery packs occupy significant space, particularly in battery electric vehicles where the need to ensure greater driving range necessitates larger batteries. Such large batteries are also heavy and likely to account for up to a third of the vehicle's total weight. The battery volume, weight and shape therefore have to be taken into proper account and require tailored design and engineering solutions from automakers, as their size cuts into legroom and imposes other design constraints.

Batteries are also key from a cost perspective. The battery pack is the most expensive component in an electric vehicle, accounting for about 30-50% of the value of a battery electric[25] and making it the most important factor in the sales price. When breaking down average Li-ion electric vehicle battery cost into its components, raw materials are the largest determinant of cost and account for some 52% of the total (see Chart 13). Within raw material costs, the cathode remains the most expensive part of any Li-ion battery configuration (about 22.4%).

[21] For this document, gigafactory is defined as a (cell) battery production facility with a capacity of 1 GWh and above.
[22] LMC Automotive, October 2021
[23] Capacity forecasts based on data from Roskill (2020) and BMI (2020), complemented by EIB analysis and estimates.
[24] BMI, May 2020.
[25] CLEPA web site.

Chart 13

Average Li-ion EV battery cost breakdown



Source: Carnegie Mellon University.

Battery technology innovation and cost reduction is set to play an important role in the future. Battery costs will be essential to (i) achieving cost and price parity between electric and internal combustion engine vehicles, thus unlocking an opportunity for even greater adoption of electric vehicles in the years to come; and (ii) increasing vehicle driving range. Many investments are still being made into battery cell chemistry and technology development. Improvements in cathode materials are the most important innovations, because the cathode is the largest component of battery cost. In the near term (the next few years), the focus will be on the improvement of existing Li-ion technologies, with the adoption of new anode and cathode materials, more stable and higher quality electrolytes and additives, better pack design and materials, and better controlled and improved manufacturing processes. The long-term (end of the decade) focus remains on the identification of technologies beyond lithium-ion, achieving a battery cost and performance breakthrough and increasing energy density (such as solid-state as an alternative to liquid electrolyte, lithium-silicon, lithium-air technologies, etc.). Solid-state, in particular, is regarded as a technology able to offer a step change. It would solve some of the environmental and safety concerns associated with Li-ion batteries by requiring fewer raw materials (such as copper and aluminium, whereas cobalt and graphite would be eliminated altogether) and by replacing the liquid electrolyte with a more stable and less flammable thin layer of solid electrolytes. It would be cheaper, increase the level of energy density[26] and let batteries handle more charging cycles before starting to degrade, in addition to holding more energy throughout their longer lifespan. Such technology is however still facing difficulties at manufacturing

[26] The energy density of conventional batteries has risen about 4% a year over the past two decades to about 700 watt-hours a litre (Wh/L), which translates to a driving range of about 500 km in a passenger car. Further increases have been difficult to achieve due to the volume that cells and liquid electrolytes take up. Solid state batteries could push the energy density of battery cells beyond 1 000 Wh/L, for a driving range of 800 km.

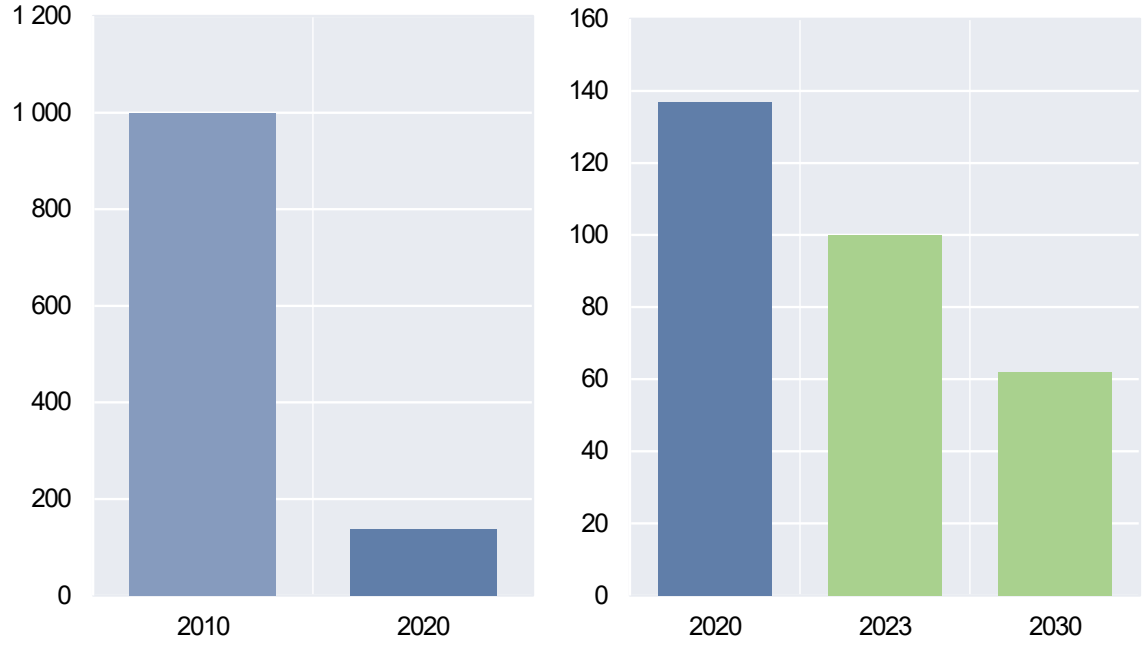
level, with costs still too high and mass production being years away. Full commercial solid-state adoption is not projected until after 2030.

Battery pack prices have been falling fast in recent years, but extrapolation of past trends needs to be applied with caution. A typical electric vehicle battery pack stores 10-100 kWh of electricity, depending on the electric vehicle it powers. In 2010, the price of an electric vehicle battery pack was over USD 1 000 per kWh. That fell to around USD 137 per kWh in 2020. The challenge for the automotive industry is figuring out how to drive the cost down further. Most industry experts agree that a common goal for the automotive industry is to reduce the price of battery packs to less than USD 100/kWh and ultimately to about USD 80/kWh. As indicated above, such levels could be achieved through improved/different cell chemistries, a more efficient use of higher-cost raw material inputs, the adoption of different engineering and design solutions (such as cell-to-pack or structural pack), and improvements in performance, learning and scale in the manufacturing processes (see Chart 14). While battery costs have declined significantly over the last decade, according to some experts these factors have been all but exhausted[27]. In contrast, since the demand for raw materials is set to increase sharply and outpace supply[28], some caution regarding predictions about how fast and to what extent battery costs will continue falling is warranted (see Chapter 4.2.2 for a more detailed discussion). The biggest future cost reductions may therefore come from a breakthrough beyond Li-ion technology, but this may not be market-ready in the next decade (Schmuch et al., 2018).

Chart 14

Battery pack cost evolution over time

Pack wholesale cost (USD/kWh)



** Cost representative of mass-market BEV model with the newest generation of the Li-ion (NMC) battery pack.*

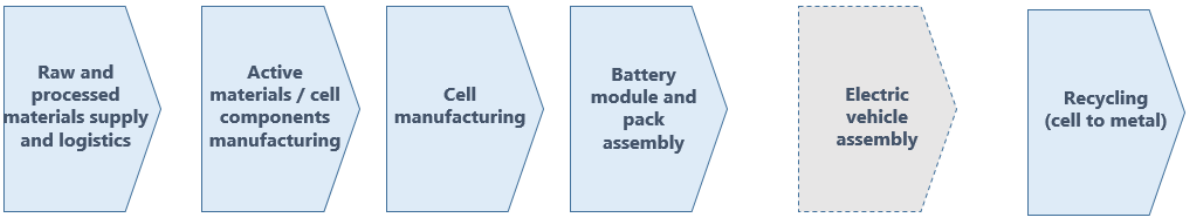
Source: BNEF; LMC Automotive.

[27] Opinion: I'm an EV expert, and I'm skeptical about how quickly electric cars will go mainstream in the U.S. - MarketWatch

[28] For instance, Benchmark Mineral Intelligence, a research group, recently concluded that in the second half of this decade the world's lithium demand might be more than twice the level of supply (see The bottlenecks which could constrain emission cuts | The Economist).

The European automotive industry in particular needs a competitive and innovative battery industry with all up and downstream stages to be developed on an unprecedented scale. While Europe still plays a leading role in terms of innovative vehicle development and manufacturing, it is currently a laggard with regard to innovative Li-ion battery manufacturing. Asia is still leading the build-up of the battery industry, supported by its industrial policies, a strong basis and almost two decades of experience in rechargeable Li-ion battery manufacturing for its consumer electronics industries. Asia currently accounts for over 80% of total installed capacity of Li-ion batteries (with China alone representing over 70% of the total), whereas Europe accounts for less than 10%. The battery supply chain is not limited to the central stages of cell manufacturing, battery module and pack assembly. It also includes the upstream stages of raw and processed materials supply and logistics, active materials and cell components manufacturing and the downstream stage of (cell to metal) recycling, after the installation and use of batteries in electric vehicles, at the end of their life cycle.

The battery supply chain



It seems that after some initial hesitation, the automotive industry is reacting, exploring and taking action to best secure supplies of batteries. Most carmakers are entering into commercial or partnership agreements with battery cell manufacturers to ensure the production capacity required is set up in the regions or in proximity to the plants where they are planning to assemble electric vehicles, and to secure battery (cell) supplies. Some major automakers are also establishing joint ventures with them or even investing in such companies. Such cross-industry partnerships and strong relationships are also critical for battery manufacturers. They serve to manage risk and help to ensure that the significant upfront investment they have to undertake to build gigafactories (normal investment tickets range between EUR 0.5 billion and EUR 2 billion, depending on the production capacity involved) will return stable revenue and profits, as electric vehicle battery technology evolves rapidly. The establishment of cell battery manufacturing capacity is normally linked to the award of long-term contracts in order to justify the investment. This requires solid relationships to be established, and in some instances also involves negotiating offtake agreements with carmakers. Most major automakers are planning to control battery pack assembly and associated battery electronics and software development and integration directly, though they diverge in how they are approaching the fundamental technology. They are not normally involved in cell manufacturing, as current cell designs are relatively mature and automakers — starting with no in-house skills and experience — would struggle to gain an advantage against existing cell producers. It is, however, likely that such an attitude could evolve in the post lithium-ion context, if carmakers step up their efforts and gain in-house expertise. There are also examples of companies that are pushing fairly aggressive vertical integration. An example is Volkswagen, which in addition to becoming a shareholder of the startup Northvolt is planning to build or open six cell battery factories across Europe by 2030, tightening its grip on the supply chain for electric vehicles. The carmaker announced that the plants would have a combined capacity of 240 GWh a year, producing cells for almost 5 million cars annually and helping the German

group achieve its ambitious electric vehicle plans. Some carmakers are also exploring the opportunity to move further up the supply chain to secure the supplies of critical raw materials (such as lithium or nickel) or active materials to be used by their suppliers in the manufacturing of battery cells. The sustainability of raw material supplies, the energy used and responsible production and assembly processes remain crucial to ensuring the long-term competitiveness and viability of operations for all industrial players and automakers, which are keen to capitalise on the green qualities of their vehicles and to avoid any reputational risk associated with their supply chains.

BOX 1: The role of charging infrastructure

At the end of 2020, around 213 000 publicly accessible electric vehicle rechargers were deployed in the European Union, approximately 10% of which were fast chargers (with more than 22 kW and up to 350 kW), for the around 1.8 million electric vehicles registered. From a quantitative point of view, this represents an electric vehicle-to-charger ratio in line or better than the EU target (10:1).

However, the distribution of recharging points is very uneven across Europe with gaps in the network (see Chart 15). Moreover, Member States' ambition with regard to the uptake of alternative fuels and their targets for infrastructure varied significantly in the absence of a common methodology to set targets. Furthermore, in 2020, the pace of charging infrastructure deployment did not meet the uptake rate of electric vehicles.

Chart 15

Distribution of fast (blue) and ultra-fast (red) public charge points

Source: T&E 2020.

The European Union is aiming for there to be at least 1 million publicly accessible recharging stations in place by 2025 (under the European Green Deal) and 3.5 million by 2030 (Fit for 55 package), with these proposals assuming an average power output of approximately 15 kW per recharging station. This will support the uptake of a fleet of 13 million electric vehicles by 2025 and 30 million by 2030.

EU ambitions are expected to be mainly driven by the revision of the AFID, the new regulation featuring binding targets for the roll-out of charging infrastructure. Distance-based targets require fast charging stations every 60 km along motorways, while fleet-based targets are to ensure that 1 kW of charging capacity is installed for every battery-powered electric car registered in a Member State. This means that if the number of electric car registrations increases more quickly, the expansion of charging must also proceed faster.

There is no one-size-fits all solution for the type of charging infrastructure used for public electric vehicle charger deployment. In general, needs vary depending on the country's market maturity. At early development stages when there is lower demand, the focus is on enabling a minimum level of spatial coverage for the charging network to provide range confidence to electric vehicle users, even though many of these stations will likely face low utilisation. As the market grows, the roll-out of (public) electric vehicle chargers is based on ensuring sufficient charging capacity at the most popular locations. This typically leads to larger stations with higher power and more chargers per location.

A significant majority of recharging occurs in private locations (home or work) and this is expected to remain the case in the future as electric vehicle range increases. However, the proportion of energy delivered by public electric vehicle chargers is expected to increase by 2030 as the number of electric vehicle users living in urban areas with no access to private parking also increases. It is therefore assumed that around 40% of all recharging events for battery electric vehicles will take place at publicly accessible recharging points towards 2030. The usage of high-powered recharging points is also expected to increase as electric vehicles perform longer journeys (as battery range increases). This will nevertheless constitute a relatively small proportion of total installed power (targets of approximately 3.5% by 2030).

Moving to the impact on the energy sector, 8-16 million electric vehicles on German roads by 2030 will entail a 4-8% increase in total electricity volumes, depending on the scenario (corresponding to annual energy demand of 16-32 TWh for total production of around 575 TWh). A fleet of 34 million electric vehicles Europe-wide would consume around 68 TWh, a small fraction of the roughly 2 900 TWh produced in 2020. Electric vehicle charging demand will therefore not have detrimental effects on energy grids. However, the electrification of the transport sector is expected increase its share of electricity production substantially (leading to a rise of 800 TWh by 2050).

Analysis of peak demand shows that uncoordinated charging (considering typical behaviour of plugging in electric vehicles at home during evening hours) impacts peak levels, requiring costly generation and causing potential grid instability. Smart charging can efficiently reshape the electric vehicle load curve, shifting the power demand to suitable times. However, recharging for long-distance mobility needs on motorways is concentrated on periods when the electrical system has margins (weekends, holiday periods, etc.) and does not present difficulties with regard to available electricity production capacities. For example, in the reference configuration for 2035, the contribution of electric vehicle recharging in motorway areas to the French national consumption peak would be limited (around 2.5 GW) compared to the national electricity consumption peak, which reached 88.5 GW on 24 January 2021.

Another relevant aspect is the business model and the key drivers of the economic viability of the electric vehicle charging network:

- Utilisation rate: This is the key to success for any charging point operator (CPO), regardless of pricing model (time, energy, etc.), since the charging station will continue to incur costs (especially for high power stations) even if it is not used. Since charging stations only generate revenue when they are in use, it makes sense for operators to strive to maximise utilisation. At the same time, if utilisation is too high, drivers will often have to wait for chargers to become free or drive to find an available charger elsewhere. If utilisation is too low, the charging point operator will be unable to cover their operating costs and capital expenses. As electric vehicle numbers grow, charging point operators expect utilisation to increase as well, enabling them to attain profitability at some point in the future. Note that not every charging station will achieve profitability. Some will be located in low-traffic areas but operated at a loss either through government subsidies or through a need to maintain the operator's geographic footprint despite the net loss. Depending on geographic footprint and operational model, estimated utilisations range from 10-40% for high power chargers and from 10-60% for normal charging points. The main reason for the variation is that utilisation rates are very difficult to predict, with dozens of companies racing to establish charging capacity to meet varying forecasts for electric vehicle numbers. Low power on-street charging is likely to have a significantly higher utilisation rate, since it takes longer to charge the vehicle and drivers will likely plan to remain parked there for some time. However, these charging stations also risk underutilisation due to drivers staying after charging is completed.

- Subsidies and grants: At present, subsidies and grants are responsible for covering the breakeven gap for the majority of charging stations. Without these important tools, public electric vehicle charging would likely not be practical, and the electric vehicle market would be sluggish.

- Roaming relationships: Modern mobility service provider apps and navigation systems enable users to search only for the charging stations that their membership will cover. A charging point operator with fewer roaming partnerships will have proportionally lower utilisation.

- Grid subscription fees: Grid subscription fees can be very costly and are incurred regardless of usage. Smart grid integration and new billing concepts can potentially avoid some of these fees. However, grid connection fees can be very expensive, particularly in remote regions.

- Location type: A fast charger located at a rest area is likely to have much more traffic than one in a rural area. Similarly, a slow charger at a rest area will not be used often compared to one in an urban area. Proximity to high traffic destinations is also important. While location is of critical importance, the actual charging experience is also key. For instance, a charging point operator that provides protection from the rain, offers a safe environment, and diligently maintains their chargers, will find happy repeat customers.

2 Automotive in CESEE

The automotive industry has gained an important role in several CESEE countries since the 1990s, including the Czech Republic, Hungary, Slovakia, Romania, Poland and Slovenia. Backed by the strong inflow of foreign direct investment in the last 30 years, the industry has been integrated into European and global value chains, car production numbers have risen, exports increased strongly, and the sector has become a major growth driver for these economies. However, the big changes and challenges faced by the automotive industry in general will likely also impact future industry performance in these countries. Together with global trends depicted in the previous section, the region also faces specific challenges (skilled labour shortages, increasing unit labour costs, low R&D, a high degree of specialisation and export dependence) that must be borne in mind.

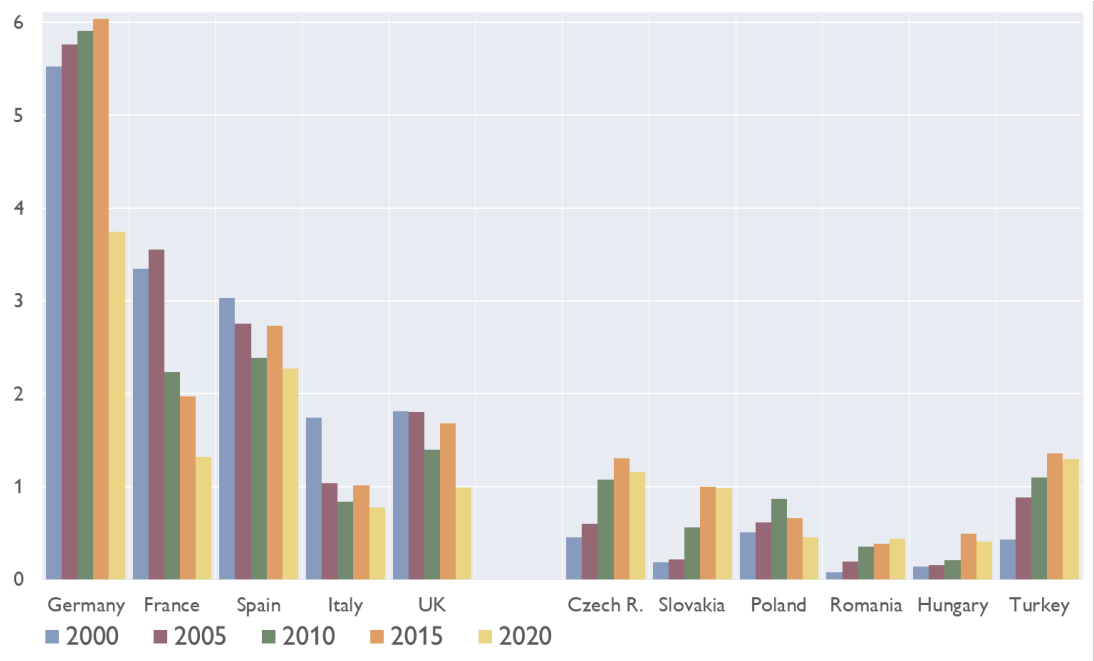
2.1 Changing hierarchies in Europe: Production moving to CESEE

In Europe, a portion of automotive production has been gradually shifting eastward over the last three decades, with Western companies grasping the historic opportunity presented by the collapse of communism in 1989. Aided by a long tradition in mechanical engineering and a well-educated workforce with complementary technical skills, CESEE countries have become the manufacturing arm of Western Europe in many sectors, but automotive production can be considered the greatest example of this.

Western automotive players have not only revitalised local brands but also shifted production eastward. For instance, in the 1990s Volkswagen acquired the Czech Skoda (founded in 1895 and under state-ownership since 1948) and Renault bought the Romanian Dacia (following a long period of cooperation starting in the 1960s). But western car producers have also moved a large share of their own production to CESEE countries, in most cases building new (and modern) factories. The Czech Republic and Slovakia — but also Romania and Hungary — have been the main beneficiaries, while France, Italy, Spain and United Kingdom have lost ground. German production remained particularly resilient until 2015, but lost more than 20% in 2015-19 and an additional 20% in 2020 due to the COVID-19 crisis (see Chart 16).

Chart 16

Vehicle production in the last two decades (millions of vehicles)



Source: OICA.

The largest share of CESEE automotive production is held by Volkswagen, which allocates almost a third of its European manufacturing to the region. Volkswagen has production in the four Visegrád countries (see Table 4) — Poland, the Czech Republic, Slovakia and Hungary. The German automaker is followed in terms of regional relevance by Stellantis (Fiat and PSA), which produces a quarter of its European vehicles in the region. Stellantis has production facilities in Poland, the Czech Republic and Slovakia (for PSA) and Poland and Serbia (for Fiat Chrysler Automobiles — FCA). Another French player, Renault, traditionally (before 2000) produced only in France and Spain. A third of its European production is now derived from Romania and Slovenia. Asian automakers also have a substantial presence. The Korean Hyundai-Kia Group is the third largest producer in the region, concentrating its facilities in the Czech Republic and Slovakia, while Toyota has been producing in the Czech Republic since 2002. While Nissan and Honda do not produce in the region, CESEE countries house the European production bases of Hyundai-Kia and Suzuki (in Hungary) — they allocate 100% of their European production to the region. US automakers have less of a presence. Ford has been producing in Romania since 2009, but its production there represents only a small share of its European car manufacturing base. General Motors owned Opel — which has factories in Poland — until 2017; Opel is now part of Stellantis Group.

Table 4

Top 15 original equipment manufacturers worldwide — vehicle production in CESEE (thousands)

World rank		PL	CZ	SK	HU	SI	RO	BG	SRB	CESEE	Tot EU	%
1	TOYOTA		88							88	508	17%
2	VOLKSWAGEN	102	858	303	105					1 368	4 725	29%
3	HYUNDAI-KIA		361	335						696	696	100%
4	GM											
5	FORD						49			49	1 100	4%
6	NISSAN											
7	HONDA											
8	FIAT CHRYSLER AUTOMOBILES (FCA)	263							72	335	1 320	25%
9	RENAULT					189	313			502	1 826	27%
10	PSA	53	108	335						496	2 552	19%
11	SUZUKI				211					211	211	100%
12	SAIC											
13	Mercedes - Benz				190						1 467	
14	BMW				from 2025							
15	GEELY										611	
	Total	418	1 415	973	506	189	362		72	3 745	15 016	25%

Note: Data as of 2017; 2016 for Toyota and Suzuki; Stellantis Group will include FCA (Alfa Romeo, Fiat, Chrysler, Dodge, Jeep, Lancia, Maserati, Ram) and PSA (Citroen, DS, Opel, Peugeot, Vauxhall).

Source: OICA.

All in all, out of 91 car factories in the European Union, 20 are located in CESEE (42 of 196 when including factories producing vans, buses, trucks and engines), according to OICA (International Organisation of Motor Vehicle Manufacturers) data.

The production range in the region has widened significantly over the last few decades. In the initial phases of the transition, CESEE countries mainly attracted the production of small vehicles (which have lower margins) and the more labour-intensive production of trucks. However, the region later moved to produce a wide range of vehicles including medium and larger cars and SUVs. Moreover, many luxury brands have been establishing production facilities in the region, especially in recent years. The Mercedes factory in Hungary was opened in 2012 as the first European Mercedes-Benz car plant outside Germany. Jaguar and Land Rover — the British brands owned by the Indian Tata Motors — opened their Slovakian factory in 2018, with a capacity of 150 000 vehicles. BMW has three-quarters of its European production base in Germany (the United Kingdom, Austria and the Netherlands account for the remaining share), but has announced its intention to produce in Hungary from 2025, with a capacity of 150 000 vehicles. Audi, part of Volkswagen Group, has been producing in Hungary since the early 1990s. Porsche has been producing in Slovakia since 2007, and has announced the construction of a new assembly plant in the country.

The eastwards move has not only involved the main automakers, but also their suppliers. This is significant, considering that around 75% of the value of a car is derived from the suppliers and this share may even increase in the coming decades due to the role of digitalisation and the arrival of new players, startups and digital technology companies on the scene. Top Tier 1 suppliers such as Bosch, Denso, Delphi, Lear, Visteon, Adient (previously Johnson Controls), Faurecia and Magna all have large production facilities in CESEE countries, with the strongest presence in Poland, the Czech Republic, Slovakia and Hungary.

As well as hosting factories from all major global automakers, CESEE countries are home to a number of young and innovative automotive companies. Croatian company Rimac — founded in 2009 by Mate Rimac (then 21 years old) — produces electric hypercars. Rimac Automobili's first model, developed in 2011, was the world's fastest production electric vehicle. In addition to producing its own cars, Rimac manufactures drivetrains and battery systems and provides electric vehicle technologies for many large automotive players, attracting investments from Hyundai and Porsche (both remain minority shareholders in Rimac). In July 2021, Rimac announced its takeover of the iconic brand Bugatti — the French-Italian company producing luxury cars since 1909 — and the creation of a joint venture, headquartered in Zagreb. Rimac will own a controlling 55% share in the new company, Bugatti-Rimac, with Volkswagen's Porsche owning the remaining 45%. Sin Cars, a Bulgarian-German-UK-based company founded in 2011 by a Bulgarian engineer and driver, has traditionally developed racing cars. More recently (since 2019), it has entered a different field, namely the development and implementation of a new multifunctional urban electric vehicle, the L City Bus. This is a zero-emission vehicle equipped with solar panels and developed for courier services, especially suitable for the last-mile delivery of goods.

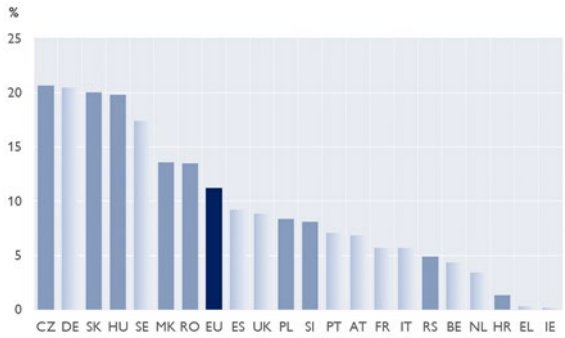
2.2 The relevance of automotive for CESEE economies

The automotive sector[29] plays an important role in the economies of CESEE countries. In sum, the automotive sector of all ten CESEE countries together generated value added of EUR 32 billion in 2018, representing 12.5% of total EU automotive value added. They are important players in the automotive sector at an EU level, and the sector is important for their economies. They are among the most automotive-specialised countries in the European Union. Measured by the share of value added in total manufacturing value added for each country in 2018 (see Chart 17), the Czech Republic is the European Union's most automotive-specialised country, with more than 20% of total manufacturing value added, closely followed by Germany, Slovakia and Hungary. North Macedonia and Romania are also among the most specialised countries, while Sweden is the only other Western European country to be included in this group. Poland and Slovenia have smaller shares, accounting for 8% of manufacturing value added.

[29] The automotive industry is defined as NACE rev. 2 C29 "Manufacture of motor vehicles, trailers and semi-trailers". It includes motor vehicles (C29.1), bodies for motor vehicles; trailers and semi-trailers (C29.2) and parts and accessories for motor vehicles (C29.3). For the discussion of the automotive industry using a broader definition, including wholesale and retail trade and repair of motor vehicles and motorcycles (C45), see Frederiksson et al. (2018).

Chart 17

Automotive sector value added in % of manufacturing value added, 2018

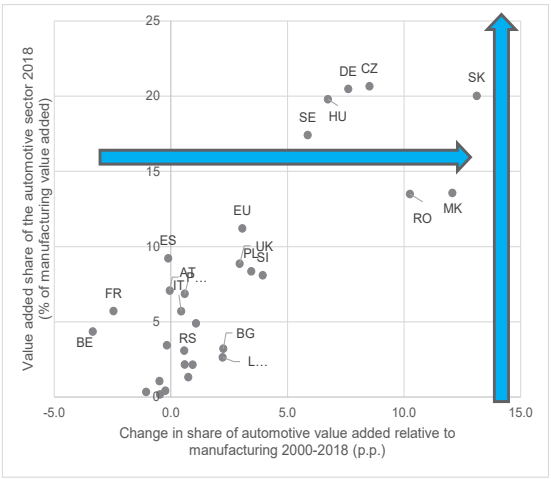


Note: Automotive sector defined as NACE rev. 2 C29 "Motor vehicles, trailers and semi-trailers". EU includes the EU27+UK.

Source: Eurostat National Accounts [nama_10_a64].

Chart 18

Specialisation and relocation: automotive sector value added share in 2018 (% of manufacturing value added) vs change in this share 2000-2018 (percentage points)



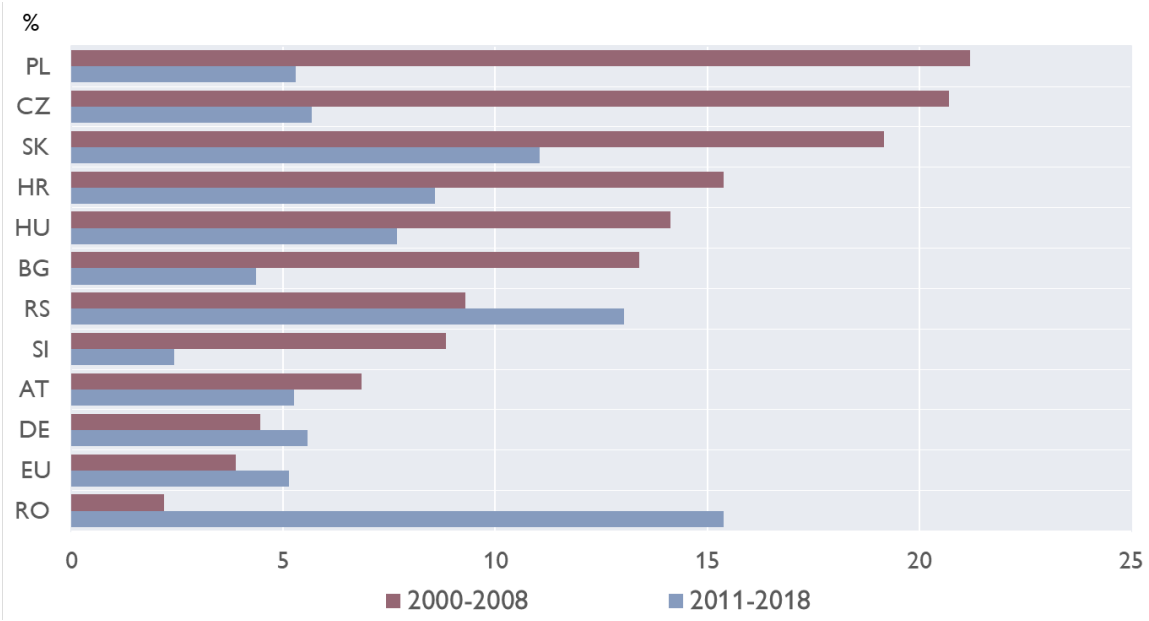
Note: Automotive sector defined as NACE rev. 2 C29 'Motor vehicles, trailers and semi-trailers'. EU includes the EU27+UK.

Source: Eurostat National Accounts [nama_10_a64].

Strong relocation of the automotive sector to certain CESEE countries mostly slowed down after the global financial crisis. The share of automotive in total manufacturing value added increased in all countries in the region between 2000 and 2018. This increase was most remarkable in Slovakia, North Macedonia, Romania, the Czech Republic and Hungary. At the same time, Germany, contrary to other EU countries, experienced a large increase in its value added share during this period. In fact, Germany, Austria and the Visegrád countries form the so-called Central European manufacturing core (IMF, 2013; Stehrer and Stöllinger, 2015). On the other hand, Belgium and France witnessed a decline in their automotive shares during this period. Austria had the same automotive share in 2018 as it did in 2000. Chart 18 depicts these trends in relocation and specialisation in the European Union. CESEE countries mostly experienced high value added growth rates between 2000 and 2008 (Chart 19), with much lower figures in the period after the financial crisis. In Poland, the Czech Republic, Latvia and Slovakia, the automotive sector's value added experienced annual average growth rates of about 20% between 2000 and 2008. In contrast, the growth of automotive value added slowed down to 5% (Poland), 6% (Czech Republic), 17% (Latvia) and 12% (Slovakia) a year between 2011 and 2018. This was still above overall GDP growth ranging between 2% and 4%. Only in Lithuania, Serbia and especially Romania did the automotive industry's value added increase more in the second period than in the first. The EU average also increased more between 2011 and 2018, thanks to better performance from Germany during that period.

Chart 19

Annual average growth rates of value added of the automotive sector, 2000-2008 and 2011-2018



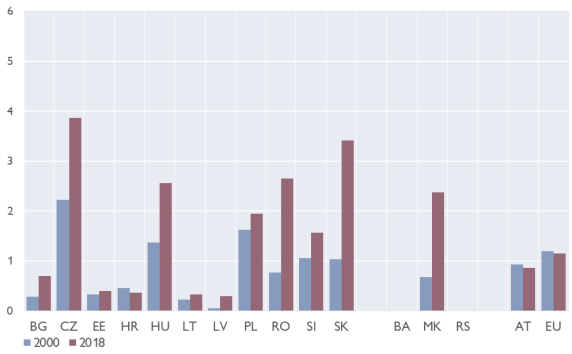
Note: Automotive sector defined as NACE rev. 2 C29 "Motor vehicles, trailers and semi-trailers". EU includes the EU27+UK.

Source: Eurostat National Accounts [nama_10_a64].

The automotive sector is also an important employer in the region. The automotive sector employed 1 million people in CESEE countries in 2018, 36.7% of total EU automotive employment. This figure was about 300 000 in Poland, 200 000 in Romania and the Czech Republic and about 100 000 in Hungary. In Slovakia, about 80 000 people were employed in the automotive sector. Looking at the share of the automotive sector in total employment (see Chart 20), employment shares were again largest in the Czech Republic, Slovakia, Romania and Hungary, followed by North Macedonia, Poland and Slovenia. In most countries, employment shares are smaller than shares of automotive in total value added due to the high capital intensity of the sector and its high robot density, even when compared to the manufacturing average. Robotisation is particularly high in automotive assembly — driven by foreign companies investing in assembly plants using robots — while car part production is more labour-intensive. Robot density (number of industrial robots per 10 000 employees) in the CESEE region's automotive sector has increased dramatically in recent years (see Chart 21).

Chart 20

Direct automotive sector employment in % of total employment, 2000 and 2018, CESEE

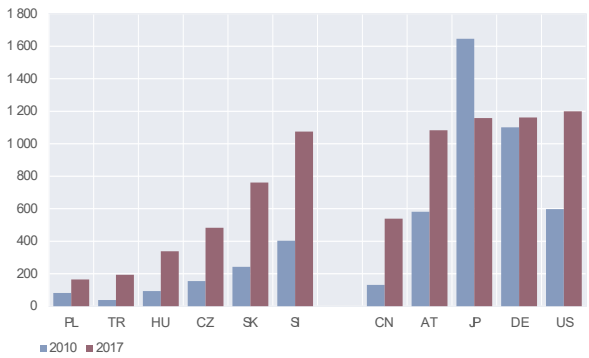


Note: Automotive sector defined as NACE rev. 2 C29 "Motor vehicles, trailers and semi-trailers". EU includes the EU27+UK.

Source: Eurostat National Accounts [nama_10_a64_e]

Chart 21

Number of industrial robots per 10 000 employees in the automotive sector



Source: IFR, OECD.

2.3 Foreign direct investment, trade and global value chains in CESEE

Foreign direct investment (FDI) has shaped CESEE economies over the last 30 years. It has restructured manufacturing and turned the region's automotive industry into a highly competitive, globally integrated sector. Looking at the total economy, Chart 22 and Chart 23 show the long-term trends in foreign penetration (inward foreign direct investment stock in percentage of GDP) in the Central Eastern European countries in the European Union and the Western Balkans. With the collapse of communism, foreign direct investment poured into the region through both privatisation and greenfield investments, with foreign investors heading first towards Hungary and Estonia at the start of the 1990s. Their FDI stock had already reached 47% of GDP by the turn of the century. The EU accessions in 2004 and 2007 further spurred this inflow in the 2000s. Since the financial crisis, however, FDI stock has remained rather flat in most countries. It has increased only in some countries (the Czech Republic, Slovenia and Latvia), while it has decreased in others (Bulgaria since 2009 and Hungary since 2012). Established foreign companies shifted dividends abroad as investments in the region matured. However, a share of profits was again repatriated for reinvestment (Szabo, 2019). Overall, the FDI stock at the end of the 2020s was highest in Estonia and Bulgaria (80%) and lowest in Slovenia — which initially had a less foreign direct investment-friendly policy — and in large countries like Poland and Romania, but also in Lithuania (about 40%).

Chart 22

Overall FDI inward stock in % of GDP in the EU-CEE

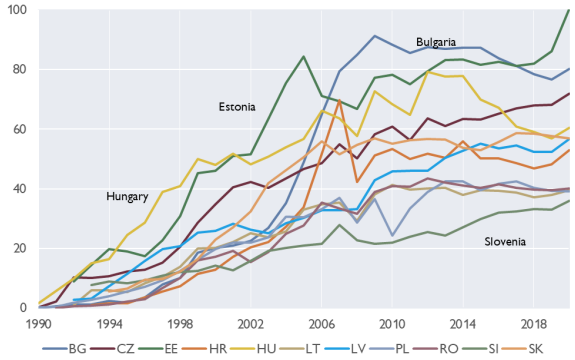
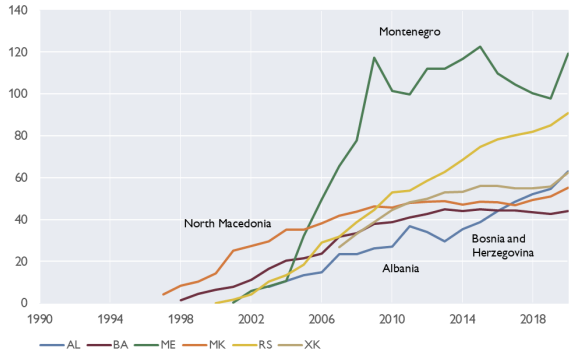


Chart 23

Overall FDI inward stock in % of GDP in the Western Balkans



Note: Special-purpose entities excluded.

Source: wiiw FDI database.

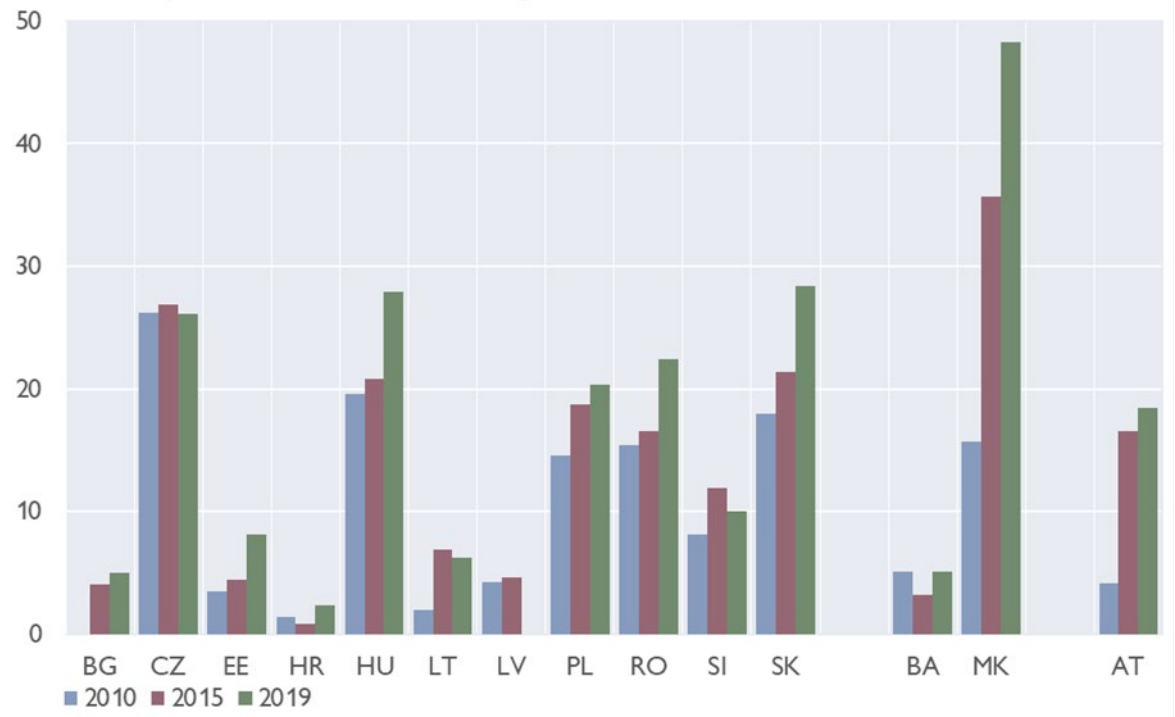
Source: wiiw FDI database.

Inflow of foreign direct investment to the Western Balkans started later, at the beginning of the 2000s. Inflows into the Western Balkans were delayed by the Yugoslav War (1991-2001) and started targeting North Macedonia and Bosnia and Herzegovina first at the turn of the century. FDI stock has skyrocketed in Montenegro since 2006, reaching its highest levels first in 2009 and then in 2015 (with 123%). This was largely due to real estate investments (Hunya, 2018). FDI stock in Serbia increased constantly and reached more than 80% at the end of 2020s, the second highest level in the Western Balkans. In North Macedonia, Bosnia and Herzegovina, and Kosovo, the FDI stock remained fairly stable during the 2010s, while that of Albania increased after 2013.

Manufacturing in general and the automotive sector in particular have been the main target for foreign direct investment in the manufacturing core countries. Foreign direct investment stock is generally concentrated in the services sector (including banking), which accounted for 50-80% of it in 2019. However, foreign direct investment in manufacturing had a prominent role in several CESEE countries. Hungary saw the highest manufacturing share (43% of FDI stock), while in several other countries it ranged between 35-25% (Slovenia, Poland, Romania, the Czech Republic, Slovakia and Croatia). Some Western Balkan countries — particularly Macedonia (38%) and Bosnia and Herzegovina (29%) — also had substantial FDI stock in manufacturing. Only the Baltic countries (especially Albania and Kosovo) had very low shares in manufacturing (12%). In countries where manufacturing had a high share of foreign direct investment, the automotive industry has typically been a major FDI target, the only exceptions being Croatia and Bosnia and Herzegovina (see Chart 24). In North Macedonia, the automotive sector accounts for nearly half of manufacturing FDI stock. This figure is a third in the Czech Republic, Hungary and Slovakia, and 20% in Romania, Poland and Austria. Between 2005 and 2019, large increases in these shares were seen in Hungary, Romania, Slovakia and North Macedonia (and to a certain extent in Estonia), while they remained rather constant in the other countries.

Chart 24

Foreign direct investment inward stock, transport equipment (NACE rev 2, CL, C29+C30) in % of manufacturing, 2010, 2015, 2019



Note: Hungary 2016 instead of 2015, Latvia 2014 instead of 2015, Slovakia 2017 instead of 2019.

Source: wiiw FDI database.

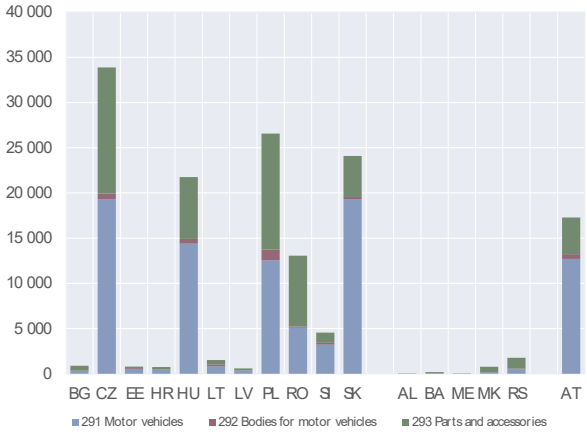
Foreign direct investment has enabled the automotive sector to become one of the CESEE region's biggest exporters. Foreign automotive companies in the region mainly produce for export markets, large automakers in particular while car part suppliers produce for export and for the domestic market. This makes the automotive sector a major exporter in countries with a large share of foreign direct investment in this sector. Automotive exports accounted for a record high of 34% of total exports in Slovakia in 2019 (see Chart 25). Hungary, the Czech Republic and Romania have a very high share too with 20%. Automotive exports play an important role in the economies of Slovenia, Poland, and the two Western Balkan countries (North Macedonia and Serbia), with shares between 15% and 11%. In Austria, the comparable share stood at 13% in 2019. In terms of overall export size and structure (see Chart 26), Slovakia and the Czech Republic are the largest exporters of motor vehicles (ISIC code 291), while the Czech Republic and Poland are the largest exporters of parts and accessories (ISIC code 293).

Chart 25

Automotive exports, in % of total, 2019

Chart 26

Automotive exports, in EUR million, 2019



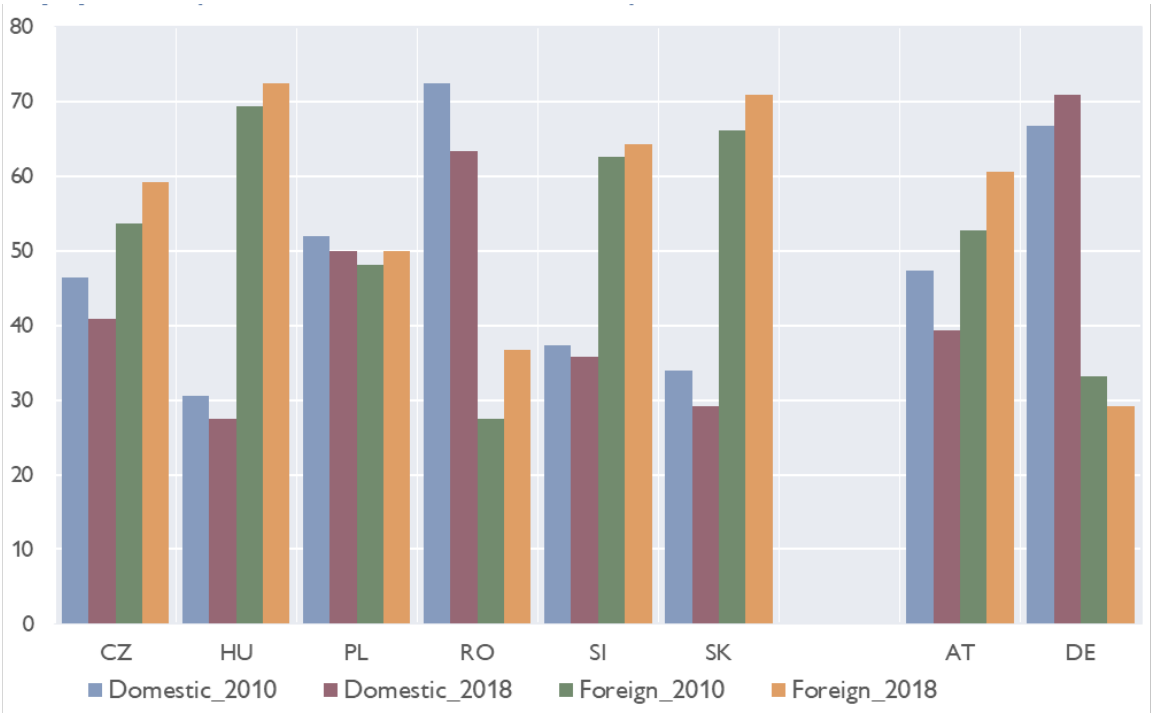
Note: Automotive sector defined as NACE rev. 2 C29 "Motor vehicles, trailers and semi-trailers".

Source: UN COMTRADE.

Foreign direct investment has shaped the integration of the automotive sector into global and regional value chains. Looking at intermediate inputs in more detail, most countries' parts and accessories exports were larger than their imports in 2019, except for Slovenia, Austria and especially Slovakia, which imported more parts and accessories. Another way to investigate the importance of imports and interlinkages is to apply input-output measures. A value chain can be described as a "full range of activities that firms and workers do to bring a product from its conception to its end use and beyond. The activities that constitute a value chain have generally been carried out in inter-firm networks on a global scale" (Gereffi and Fernandez-Stark, 2011). Value chains are therefore deemed to be global. Participation in global value chains is particularly high for the CESEE region (World Trade Organization (WTO), 2021). In addition, the automotive industry has among the longest value chains of any industry, ranking just below television and communication equipment (OECD, 2012). Overall, the global value chain participation of the region's automotive industry is therefore very high. However, it should be borne in mind that the automotive industry is organised into three main blocks that generally source within their respective regions: the European Union, North America and Asia (OECD, 2012). The wiiw multi-country input-output database (wiiw MC-IOD, Reiter, Stehrer, 2021) — which also includes the Western Balkan countries — can be used to analyse the value added content of transport equipment exports. Production integration can then be analysed by looking at the value added in a country's exports. Chart 27 shows the value added embodied in exports and splits it into domestic and foreign portions. The domestic portion was particularly low for Hungary, Slovenia and Slovakia in 2018 (about 30%), while it was slightly higher for the Czech Republic (40%), Poland (50%) and especially Romania (60%). For comparison, the domestic share stood at 47% in Austria and an astonishing 71% in Germany in 2018. Conversely, the foreign portion was highest for Hungary, Slovenia and Slovakia (reaching 70% of exports in 2018), while it was lower for the other countries. Between 2010 and 2018, the domestic portion declined in all countries, while the foreign share increased.

Chart 27

Domestic and foreign value added content of exports of transport equipment (NACE rev. 2, CL, C29+C30), 2010 and 2018

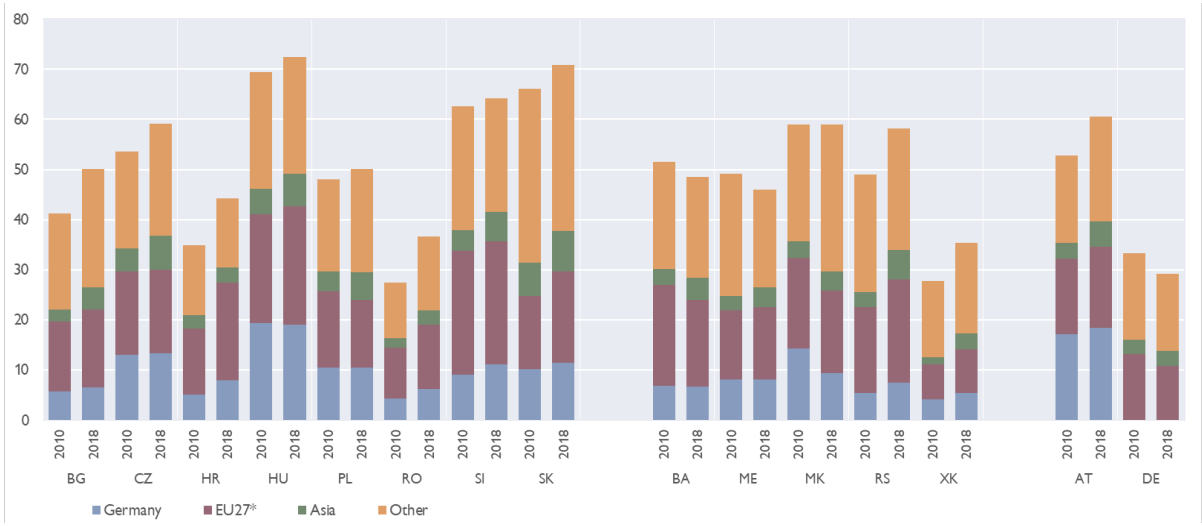


Source: wiiw multi-country input-output database (wiiw MC-IOD).

Strong interlinkages with Germany have developed. As described above, interlinkages with other countries and integration into value chains are shaped by foreign direct investment. This means that German value added content constituted a major share of exports in Hungary (19%) and the Czech Republic (13%), as well as in Slovenia, Slovakia and Poland (11%). Austria also has traditionally strong ties with Germany, with German value added accounting for 18% of Austrian transport equipment exports. Between 2010 and 2018, German shares mostly increased (except in North Macedonia, where it fell). Value added content of the remaining EU27 lay between 13% (Romania and Poland) and 24% (Hungary and Slovenia) and also grew slightly between 2010 and 2018. The Asian share was generally tiny and only somewhat larger for Slovakia (8%) and the Czech Republic (7%) in 2018 (see Chart 28).

Chart 28

Foreign value added content of exports of transport equipment (NACE rev. 2, CL, C29+C30), 2010 and 2018



Note: EU27 denotes EU27 without domestic and Germany. Asia includes China, South Korea and Taiwan.*

Source: wiiw multi-country input-output database (wiiw MC-IOD).

BOX 2: Factory economies: Functional specialisation patterns in the automotive sector

Based on the work of Stoellinger (2021), this box explores functional specialisation patterns in the automotive sector in more detail. The relative functional specialisation measure (RFS) is derived by applying the concept of revealed comparative advantage (RCA) to inward greenfield foreign direct investment data taken from fDiMarkets (www.fdimarkets.com, a division of Financial Times Ltd) and interpretation is similar. Differences in specific value chain functions can thus be mapped for the automotive sector. The following value chain functions are distinguished: (i) headquarter services (HQ); (ii) R&D; (iii) production; (iv) sales, logistics, marketing and support services; and (v) business services and technical support. Looking at the example of the Czech Republic and Germany in Chart 29 and Chart 30, we see opposite functional profiles in these two economies. The automotive sector in the Czech Republic shows a revealed comparative advantage in production (RFS of 1.28), but other more skill and knowledge-intensive pre and post-production functions — including headquarter services and R&D, but also sales and business services — are underrepresented (RFS below 1). Conversely, Germany's automotive industry has a comparative disadvantage in production, but substantial comparative advantages in headquarter services, R&D and business services. In fact, functional specialisation patterns in the automotive sector (and elsewhere) are quite similar across CESEE countries, which serve as factory economies in the European production networks. The patterns of Western European countries are also alike, enabling them to take the role of headquarter economies (Baldwin and Lopez-Gonzalez, 2015). This might have consequences for the CESEE countries as lower value added creation is associated with the production value chain function — the so-called smile-curve hypothesis (first introduced by Shih, 1996) — meaning that they may be caught in a functional specialisation trap. Depicting the relative functional specialisation over time (see Chart 31 and Chart 32) might give an answer to this question. Indeed, there was an increase in R&D and business services in the Czech Republic over time and a tiny decline in production. However, these changes were rather small.

Chart 29

Czech Republic: Relative functional specialisation (RFS) of the automotive sector, 2003-2015

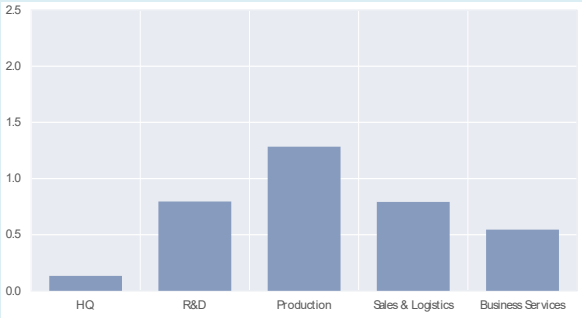
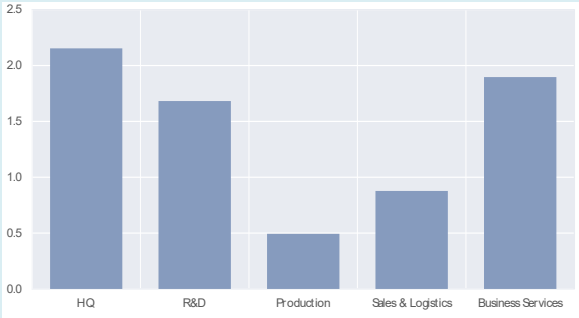


Chart 30

Germany: Relative functional specialisation (RFS) of the automotive sector, 2003-2015



Note: Automotive sector defined as NACE rev. 2 C29 "Motor vehicles, trailers and semi-trailers".
Data based on the fDI markets database.

Source: Stoellinger (2021).

Chart 31

Czech Republic: Relative functional specialisation (RFS) of the automotive sector, three periods

Chart 32

Germany: Relative functional specialisation (RFS) of the automotive sector, three periods

Note: Automotive sector defined as NACE rev. 2 C29 "Motor vehicles, trailers and semi-trailers".
Data based on the fDI markets database.

Source: Stoellinger (2021).

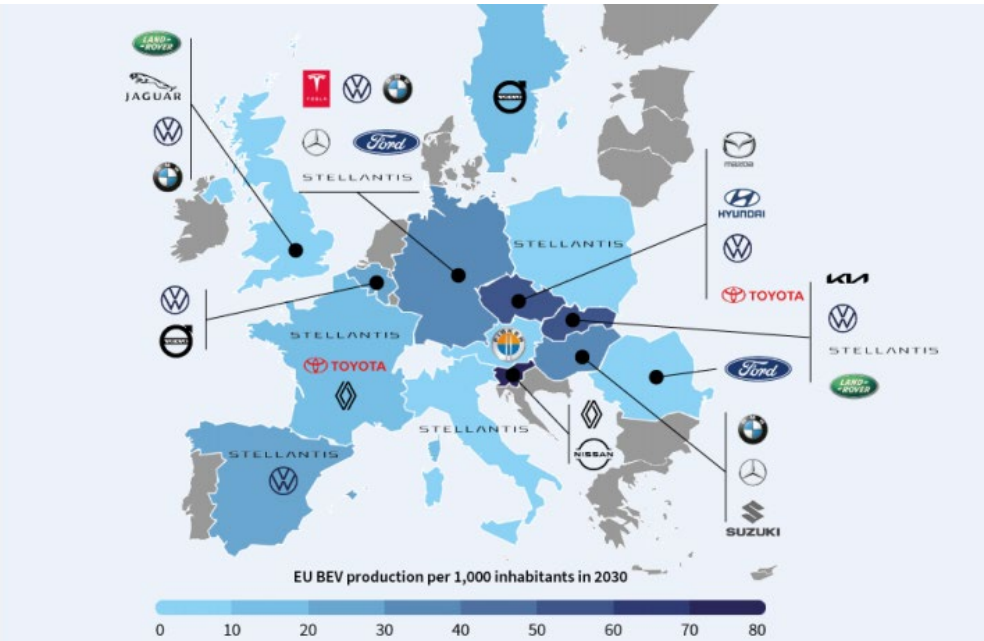
2.4 Vehicle electrification moving eastwards

Although the picture across the region is somewhat varied, several CESEE countries are fully involved in the electrification process and appear to have the potential to reap significant benefits from the electrification trend. The European electric car production landscape is changing rapidly as all major automakers are quickly adapting their strategies to the evolving market demand and to the new regulations, especially related to the European Union's Fit for 55 package, presented in July 2021. As mentioned in Chapter 1.3, almost all major European players have been scaling up their electromobility ambitions. CESEE automotive factories are heavily affected, given their high level of dependence on the strategies of major automakers and on the decisions taken in their respective headquarters. In many cases, countries in the region are expected to benefit: a large majority of the models they produce are set to be electrified and electric production in their factories will increase. Some CESEE countries have the potential to become key focal points for electric production, at least based on announcements by major automakers. For instance, Slovenia, Slovakia and the Czech Republic are expected to have the highest level of battery electric vehicle production per capita (50-80 battery

electrics produced per capita in 2030), according to Transport & Environment (2021) analysis based on IHS Markit car production forecasts (see Chart 33). Moreover, vehicle production in some countries in the region is projected to become exclusively (Slovenia) or predominantly (for example, Poland) focused on battery electric vehicles (see Chart 34). However, in other countries like Romania, the shift to electric vehicle production will be less significant.

Chart 33

Forecast of Europe's battery electric vehicle production per population unit in 2030



Note: Only carmakers with battery electric vehicle production above 10 000 units are displayed.

Source: Transport & Environment, based on IHS Markit car production forecast (202106_EV_Report-Final (transportenvironment.org)).

Czech Republic: All automotive players producing in the country (Skoda, Hyundai and Toyota) have launched at least some full electric vehicle or hybrid production. Skoda (Volkswagen Group) — which is investing EUR 2 billion in e-mobility and wants the Czech Republic to be an electromobility hub — has announced that by 2025 it will have ten electrified models (six will be all-electric, the others plug-in hybrids and hybrids). Skoda currently offers three electrified models. Hyundai has started producing the Kona Electric (around 30 000 vehicles per year are expected) at its Czech manufacturing plant. Toyota plans to produce the new Yaris (including hybrid electric technology versions) in the Czech Republic.

Slovakia: Stellantis has EUR 180 million in investment plans in Slovakia, with the aim of gradually launching mostly hybrid and electric vehicles. PSA (now Stellantis) produced its first electric car in Slovakia in 2019; the Peugeot e-208 will be produced exclusively in Slovakia. Volkswagen — which sold more electric cars in Europe in 2020 than any other brand (followed by Renault-Nissan and Tesla) and is among the best prepared for the electric transition (Transport & Environment, 2021) — has been producing its electric car (the e-Up!) in Slovakia since 2013, but more detailed future plans are yet to

be disclosed. Jaguar Land Rover's plug-in hybrid electric cars will come in addition to production of the Defenders.

Poland: Car production in Poland largely depends on Stellantis, the only carmaker active in the country (other players produce vans and trucks). FCA is investing EUR 165 million in its Polish plant to produce new hybrid and electric vehicles (the Tychy plant currently builds the Fiat 500 and Lancia Ypsilon small cars). New hybrid and electric Jeep, Fiat and Alfa Romeo models will be built in 2022. Volkswagen's Polish plant in Wrzesnia is taking over complete production of the zero-emission e-Crafter van. The same plant already produces fully electric vans under the MAN brand (MAN eTGE). Poland is already the leader in the manufacturing of electric buses, with Solaris producing vehicles for cities across Europe. Moreover, in 2020 the Polish government announced plans to build an electric vehicle factory. ElectroMobility Poland, a state-owned company, would launch its e-cars under the Izera brand in the autumn of 2024.

Hungary: BMW will start production in 2025, with a capacity of 150 000 cars per year. The BMW plant in Debrecen will exclusively produce electric cars, making it the key focal point of BMW's strategy for electromobility. Daimler has announced plans to invest EUR 141 million in Hungary to add fully electric vehicles from the fourth quarter of 2021 onwards. The electric drives for the Audi e-tron have been manufactured in Hungary since 2018, and production of electric motors was expanded in 2019 (from 2026, Audi will only launch new all-electric models). The electric models for the Premium Platform Electric (PPE), developed jointly with Porsche, are also to be assembled at the Hungarian plant. 65% of the cars produced by Magyar Suzuki in 2020 were already hybrids, with this share surpassing 70% in 2021.

Slovenia: The Renault Twingo EV already accounted for one-third of the Revoz plant's output in 2021. In addition to Clio and Twingo production, the Slovenian plant also manufactures the Smart Forfour EV under a partnership with Daimler.

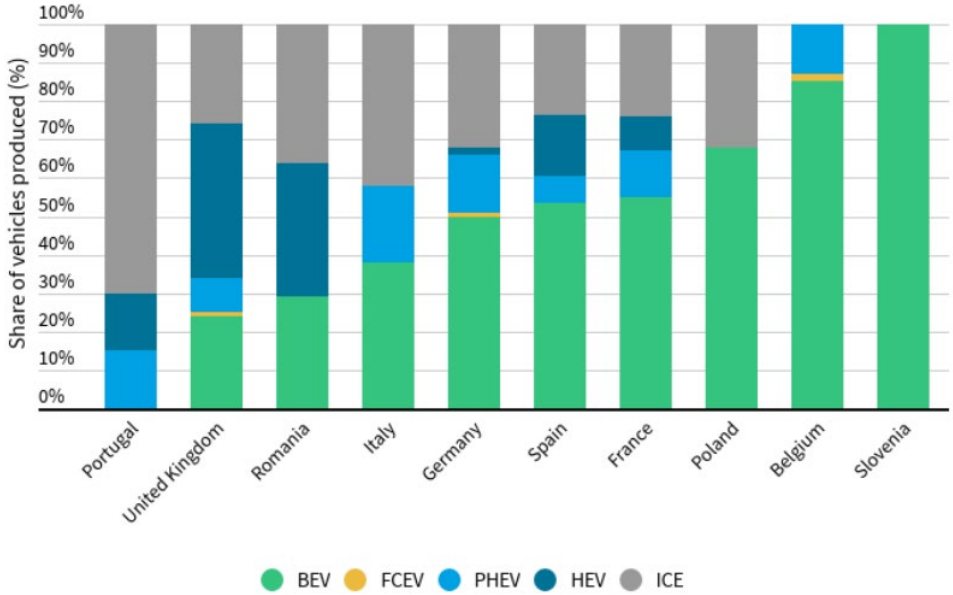
Romania: Dacia (Renault Group) has unveiled its first 100% electric model (Dacia Spring), the market's most affordable electric vehicle. However, the car will not be made at Dacia's plant in Romania, but rather at parent company Renault's facility in Shiyan, China. Ford has announced plans to invest USD 300 million in Romania, aiming to electrify the entire commercial vehicle range (all models will have an electric version to debut in 2024), and will start producing light commercial electric vehicles in Romania in 2024. Production of the hybrid Ford Puma started in 2019.

Bulgaria: The Bulgarian manufacturing facility (EUR 143 million investment) of German electric car manufacturing startup Next.e.Go Mobile is scheduled to begin operations in 2024, with the aim of producing over 30 000 fully electric cars per year.

Croatia: Rimac has been at the forefront of electromobility since its inception, and currently produces electric hypercars and supplies other established producers.

Chart 34

Fuel type production share expected in 2030 in some EU countries and the United Kingdom

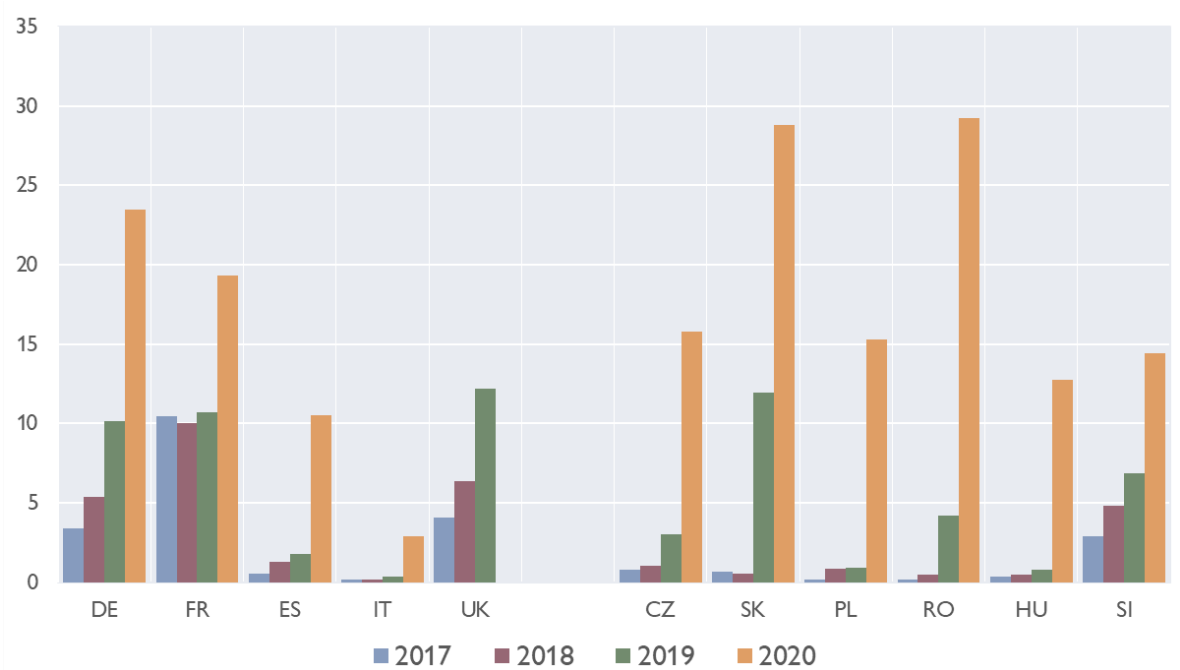


Source: IHS Markit, Transport & Environment, Automotive, European Light Vehicle Production based Powertrain Forecast, April 2021.

Going hand-in-hand with the rising production of electric vehicles in CESEE is the rising significance of electric powertrain technologies in the region's exports. In line with the general trend described above, major car producers in the region have seen a significant increase in the share of electric vehicles in total car exports in recent years, with a particularly strong jump in 2020. While the Czech Republic, Poland, Hungary and Slovenia saw the share of electric and hybrid exports in total exports increase to 15% in that year, in Slovakia and Romania this climbed to 30% (see Chart 35). For comparison, 23% of German exports were alternative cars, while this figure was 19% in France, 10% in Spain and only 3% in Italy.

Chart 35

Exports of electric and hybrid cars, in % of total cars, 2017-2020



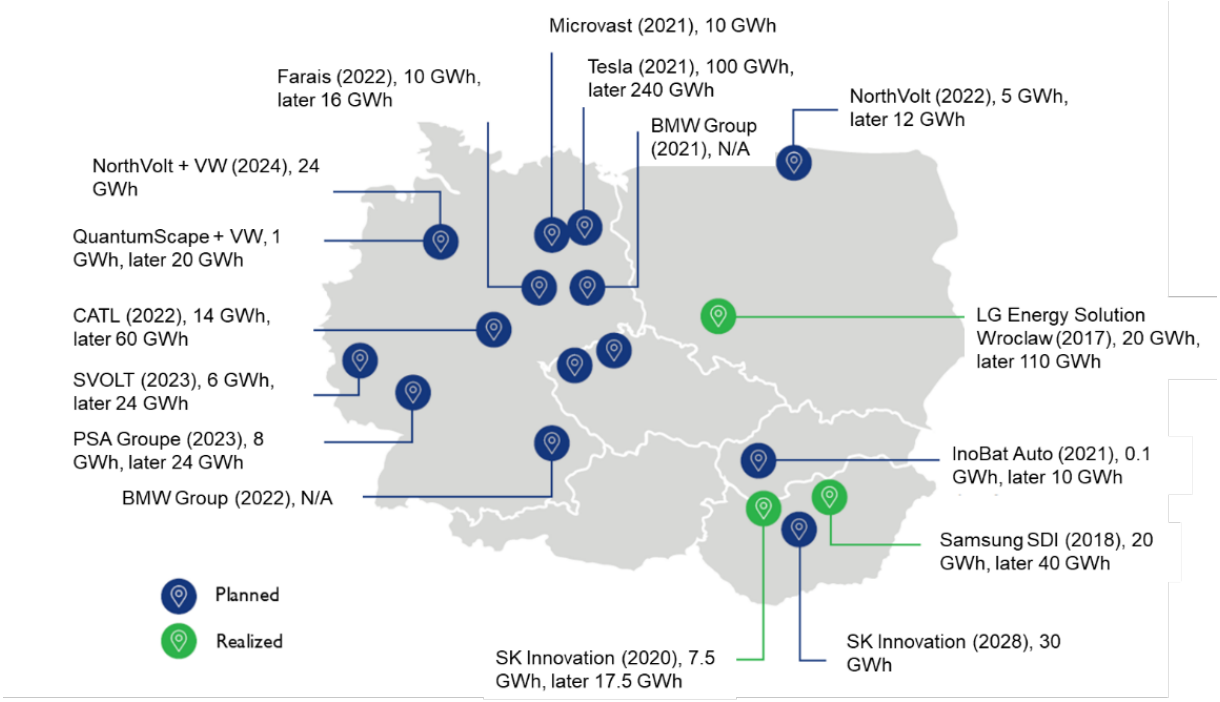
Note: Total cars denotes motor cars and other motor vehicles principally designed for the transport of less than ten persons (CN8703). Alternative cars include hybrid cars, plug-in models and pure electric cars. 2020 data for the United Kingdom not available.

Source: Eurostat Comext.

In addition to electric vehicle production, the region also doing its best to secure a role in battery production. According to Deloitte (2021), in Germany, Slovakia, Czech Republic, Hungary and Poland alone (V4+DE) there will be demand for batteries totalling some 480-650 GWh in 2040. Depending on the average capacity, this translates to 16-22 gigafactories that will have to be built as a necessary pre-condition for electric vehicle assembly to stay in the region. The countries in the V4+DE region have realised the future importance of battery production capacities, and are making significant efforts to attract investors to build gigafactories. As Chart 36 suggests, while there has already been a gigafactory in operation in Poland since 2017 and there are two in Hungary, one more is currently planned in each of these countries. In addition, one gigafactory is planned in Slovakia and (up to) two in the Czech Republic. Poland, whose exports of Li-ion batteries already amount to 2% of total Polish exports, has attracted investments in gigafactories by means of direct financial support (for example, the existing gigafactory received EUR 95 million), free land transfer and tax incentives. Similarly, the Hungarian government has incentivised investments in its two existing gigafactories and planned future ones via direct financial support of approximately EUR 100 million each, as well as free provision of the enabling infrastructure or some utilities (water). Germany has earmarked EUR 1 billion to support local battery production between 2019 and 2022. Slovakia set up the Slovak battery alliance (an independent advocacy group) in 2019. The alliance is part of its European counterpart and aims to kick start the battery industry in Europe and to participate in the European battery value chain. In addition, the Slovak government has released EUR 5 million for the initial phase of a gigafactory planned by InoBat Auto. In the Czech Republic, the government has so far only signed a memorandum of understanding with electricity company CEZ concerning support for a gigafactory project. Further concrete steps have yet to be detailed.

Chart 36

Planned and realised gigafactories in Central Europe



Source: Deloitte (2021).

Yet despite the strong involvement of the CESEE region in electrification, the implications are far more complex. The increasing shift in production volumes from internal combustion engine to electric vehicles will have repercussions for some parts of the industry in the region (particularly firms focused on the production of internal combustion engine-related parts such as transmissions or engines), while it will provide new chances and opportunities (for newcomers) in the electric vehicle business. For instance, the decision of Volkswagen not to offer new models introduced after 2023 on the European market with a manual transmission option might also have implications for Skoda. The Czech car producer is responsible for research and development and — to a large extent — for the production of transmissions for the whole Volkswagen Group. On the other hand, however, some car producers in the CESEE region (such as Skoda and Dacia) are planning a much slower transition to electric vehicles as they have been and will be serving markets where the onset of electromobility will be slower than in Europe, the United States or China. Skoda for instance has been mandated to manage activities and especially to strengthen the position of the entire Volkswagen Group in India and South-East Asia. This involves the launch of a slew of competitively priced mass-market cars. To this end, Skoda has also been mandated with research and development of cars on a common platform (MQB-A0) for the entire Volkswagen Group and all worldwide markets. Based on this platform, individual car brands in the Volkswagen Group will produce vehicles destined (in addition to Europe) in particular for India, Russia, South America and Africa. While this case exemplifies that fact that car manufacturers in CESEE (and elsewhere) will need to find a right balance between electric and internal combustion engine vehicles depending on the markets they serve, it also highlights another phenomenon reinforced by electromobility. The large investment needs in new and old technologies on the one hand and high uncertainty on the other force car manufacturers to seek further scope for rather complex optimisation. In the case of Volkswagen Group, this means that one of the group's brands is responsible for research and development of models based on the same platform for different brands in the group. In addition to cars based on MQB-A0, Skoda has been charged with developing successor

models to the Skoda Superb and Volkswagen Passat. However, the production of both cars is expected to be moved from Germany and the Czech Republic, respectively, to Volkswagen's production site in Slovakia's capital Bratislava.

2.5 Innovation and patents in CESEE: A strong focus on transportation and electric vehicles

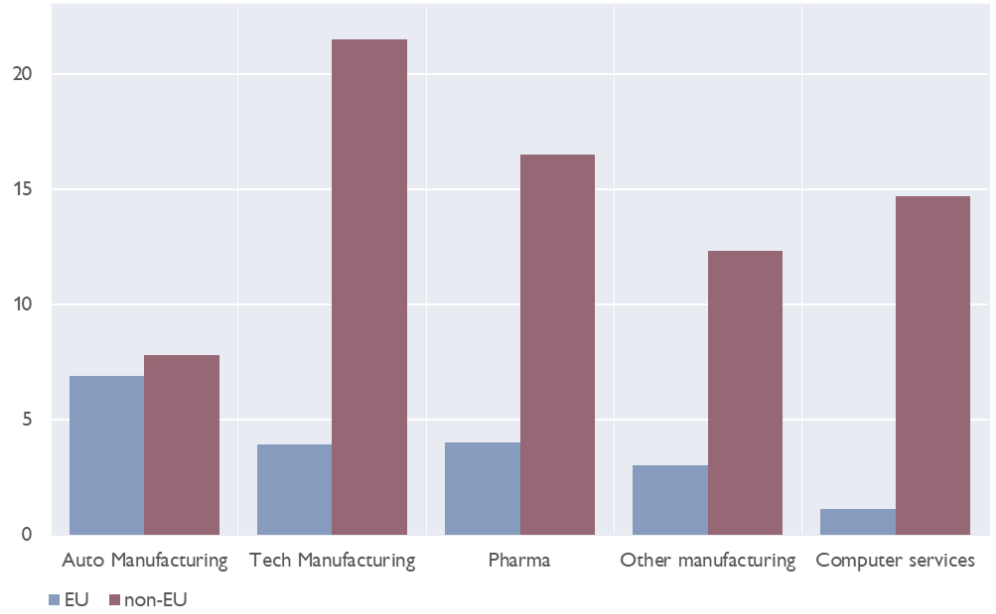
Europe is a global leader in business R&D investment in the automotive industry. One euro out of three spent in R&D in the European Union goes to the automotive sector. Global R&D expenditures by car manufacturers are heavily concentrated in a few EU countries (notably Germany and France), Japan and South Korea, and reached EUR 133 billion in 2019. The importance of US car manufacturers has fallen over time, while the presence of China is becoming more evident, particularly as the country develops electric vehicles (EIB, 2019).

Between 2012 and 2017, the German car manufacturer Volkswagen was systematically ranked as the company spending the most on R&D every year. However, the global R&D landscape has changed rapidly over the past decade as the digital economy increased in importance. In more recent years, the largest R&D investors are US and Asian companies selling software and computer services or producing electronic and hardware technology equipment. With more than EUR 23 billion spent in 2019, Alphabet (the parent company of Google) was the top global R&D investor, followed by Microsoft, Huawei, Samsung and Apple. With more than EUR 14 billion invested in R&D in 2019, Volkswagen was the sixth largest global R&D investor; it was also the only EU company in the top ten. In the same year, Daimler and Toyota spent more than EUR 9 billion each and were ranked the 11th and 12th largest global R&D investors.

Europe's strength in the automotive industry is not apparent in other sectors (see Chart 37). The European Union accounts for a smaller share of R&D expenditures in other manufacturing industries and is almost absent from software and computer services (EIB, 2020).

Chart 37

Global business R&D expenditures in 2019 (% of total)



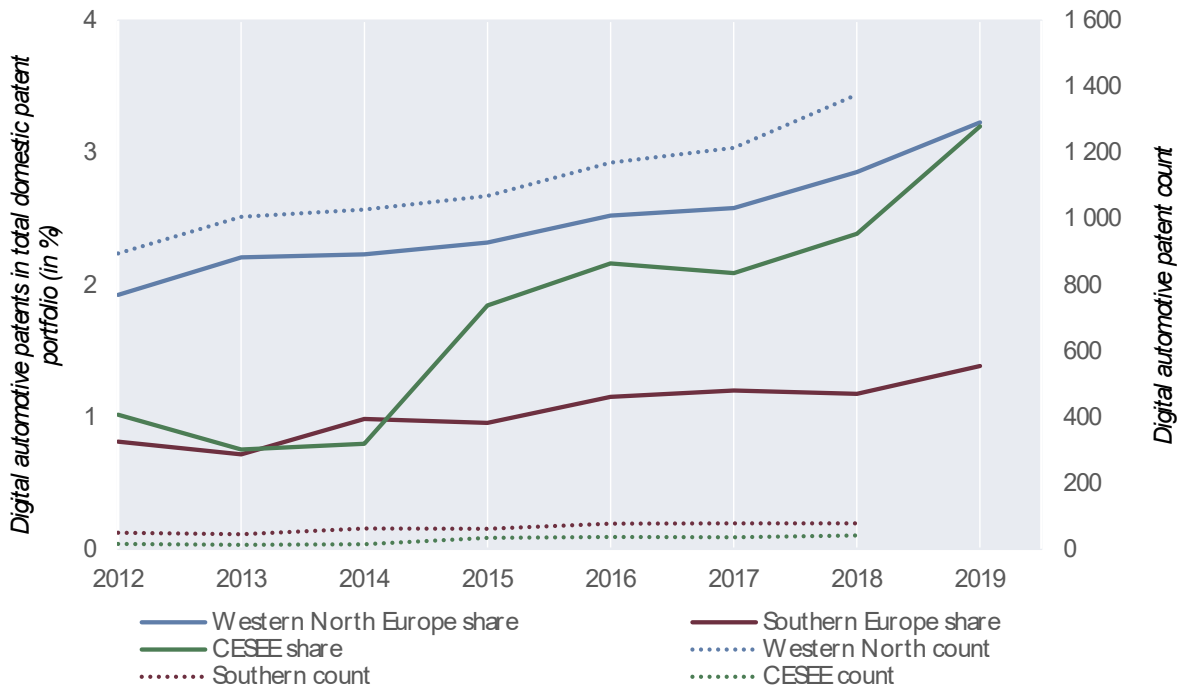
Source: EIB calculations based on EU Industrial R&D Investment Scoreboard.

Confirming the trends in R&D spending, the European Union is in pole position for the development of innovation in the automotive sector, when measured by patent data.[30] Europe shows a steady upward trend for automotive patents (see Chart 38). China and the United States are lagging behind the European Union, with less than half the number of patents and a lower relative specialisation (as measured by the patent share) in the development of automotive technologies.

[30] This section draws upon patent data from PATSTAT (a data set developed by the European Patent Office, EPO), measuring the rate of successful R&D investments of innovations that are not necessarily available on the market (yet).

Chart 38

Evolution of patents in automotive in European Union, United States and China



Note: The classification of 'digital' domains is broadly based upon the methodology of EPO (2017).
Source: Authors' calculations based upon PATSTAT (PCT) data in collaboration with ECOOM (Centre for R&D Monitoring, Leuven, Belgium).

While the number of patents related to automotive innovation in CESEE is rather low compared to the other European regions, the relative specialisation in this area is high. Automotive patents account for close to 8% of all patents in the CESEE region. This is in line with the share in Western and Northern Europe and points to an important relative specialisation in this area (see Chart 39). At the same time, Europe is in a leading position for innovation in technologies tackling climate change, with a main focus on the transportation sector (EIB, 2021). Both in terms of absolute counts and the share of patents, the European Union is at the forefront of international patenting in these areas.

Chart 39

Patents in automotive: number and share of automotive patents in Europe (2017-2019)

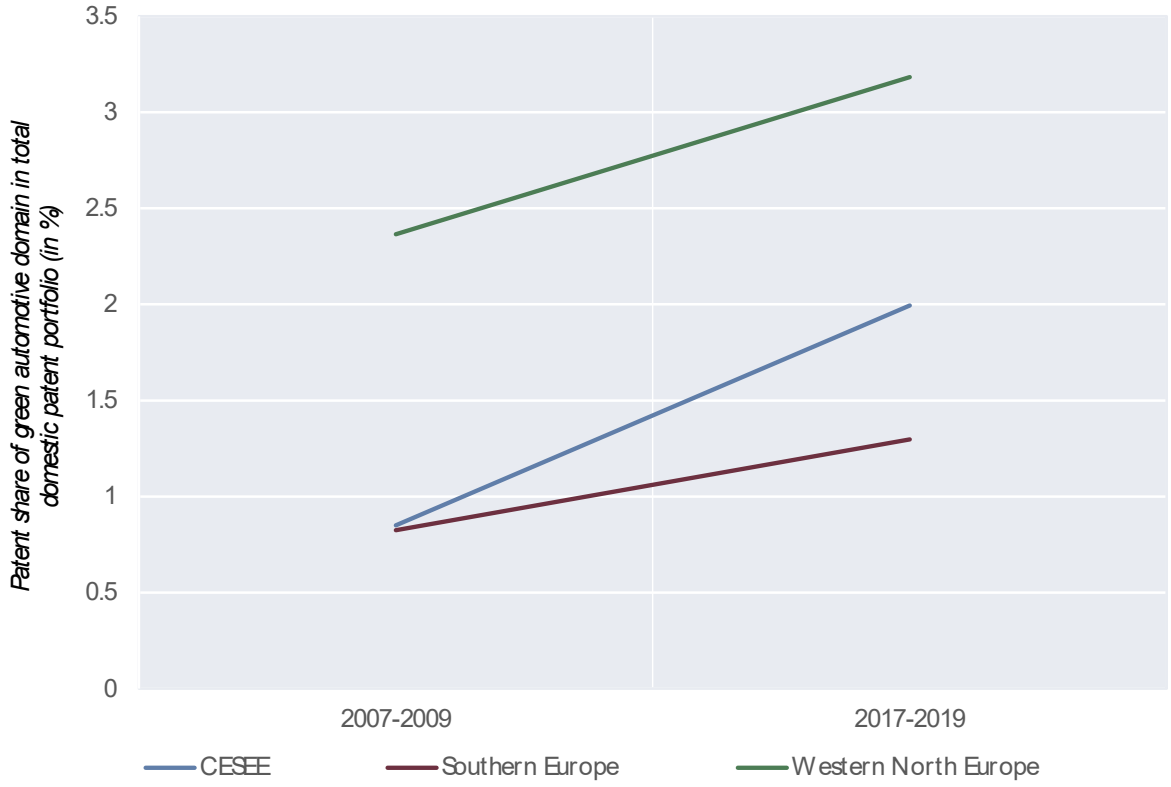
Source: Authors' calculations based upon PATSTAT (PCT) data in collaboration with ECOOM (Centre for R&D Monitoring, Leuven, Belgium).

While not a main contributor in absolute terms, the CESEE region has clearly seen major uptake of climate-friendly patents in the automotive sector (see Chart 40). Although it is still lagging behind Western and Northern Europe and slightly below Southern Europe in its absolute patent count, this is nevertheless a positive evolution for the region and could be a determining factor for future specialisation and innovations.

The focus of climate-related patents on the automotive sector in CESEE is mainly related to electric vehicles, both the development of the vehicles themselves and patents related to electric vehicle charging (see Chart 41 and Chart 42). This relative specialisation in electric vehicles is stronger than in Western and Northern Europe or Southern Europe.

Chart 40

Evolution of green automotive patents in Europe over time



Note: The classification of "green" domains is broadly based upon the methodology of Haščič and Migotto (2015).
Source: Authors' calculations based upon PATSTAT (PCT) data in collaboration with ECOOM (Centre for R&D Monitoring, Leuven, Belgium).

Chart 41

Number of green patents in transport sector (2018)

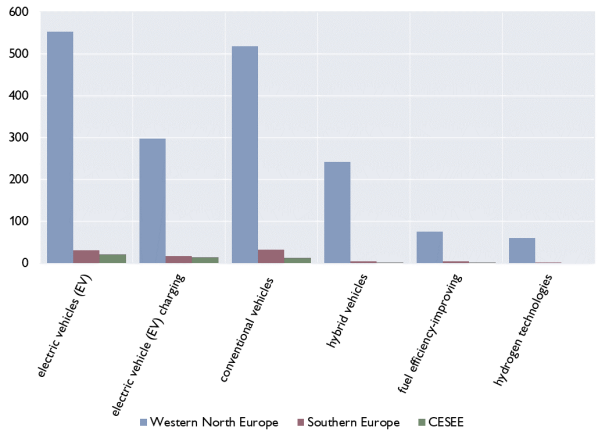
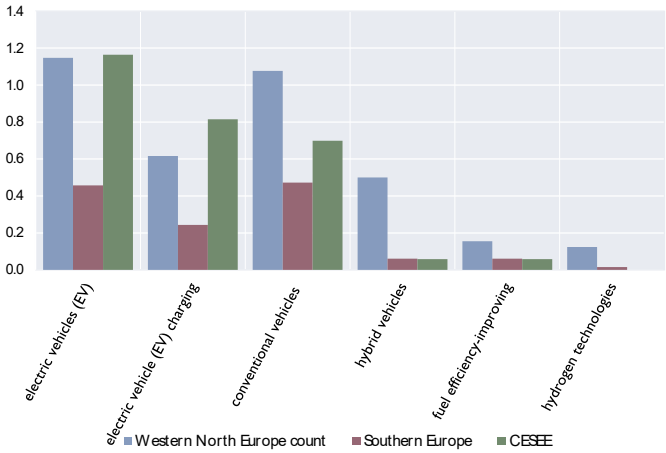


Chart 42

Share of green patents in transport sector (2018)



Note: The classification of 'green' domains is broadly based upon the methodology of Haščič and Migotto (2015).

Source: Authors' calculations based upon PATSTAT (PCT) data in collaboration with ECOOM (Centre for R&D Monitoring, Leuven, Belgium).

Some of the technologies developed in the transport and mobility sector are closely related to the area of energy. The development of electric vehicles and the application of hydrogen technology are highly dependent upon evolutions in the energy sector and the fuel efficiency levels that can be

attained. If coal and other polluting fuels used to generate the electricity needed to charge electric cars are not phased out rapidly, progress in this area will not pay off.

Europe seems to have a competitive advantage in developing innovations in wind energy, while solar is not the European Union's main area of expertise. Patents in electricity generation are focused on two key technologies: wind and solar photovoltaic energy. While Europe is establishing its presence in the former, China is the main force behind the latter.

The CESEE region does not have similar relative specialisation in electrification technologies or supporting innovations. Chart 43 and Chart 44 suggest that CESEE countries, while having created a knowledge centre in the electrification of vehicles, will have to rely to a large extent on other regions for innovation in renewable energy and the related supportive technologies in making the electrification of vehicles truly climate-friendly.

Chart 43

Climate change mitigation technologies related to electrification

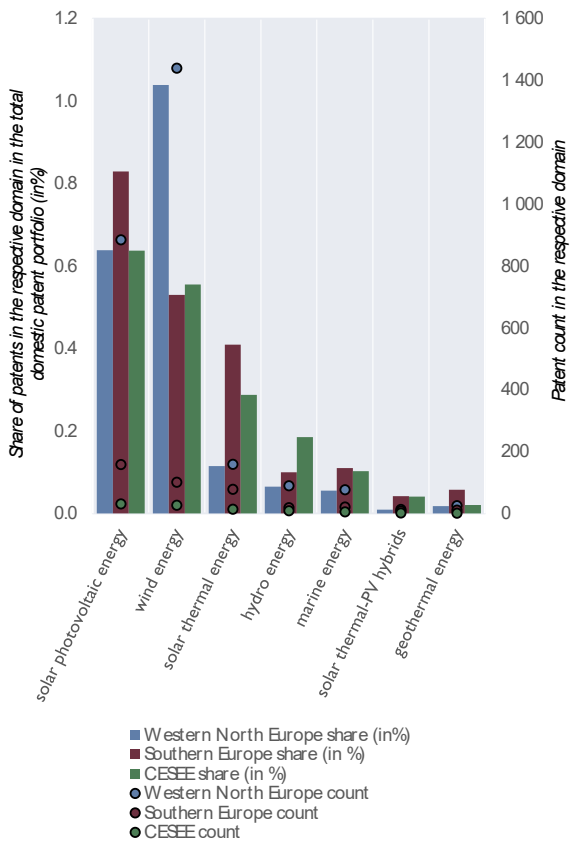
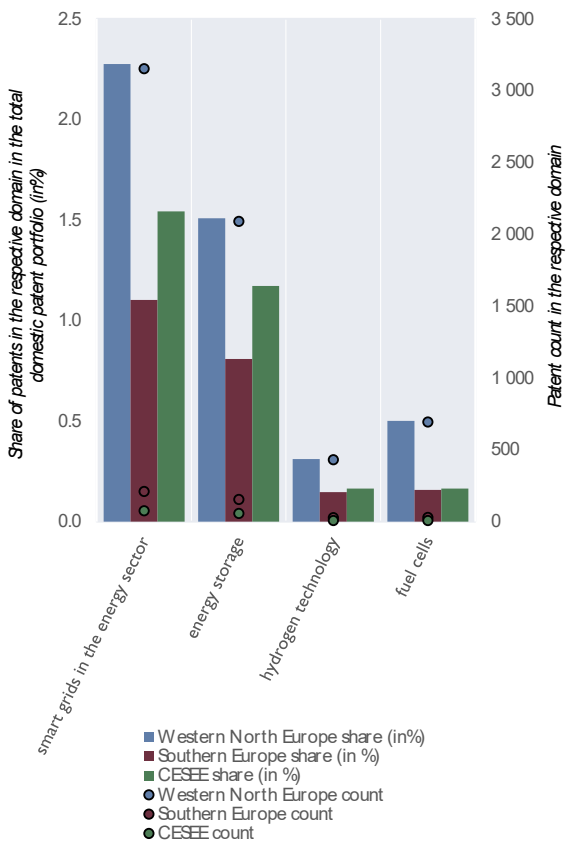


Chart 44

Climate change mitigation technologies supporting electrification



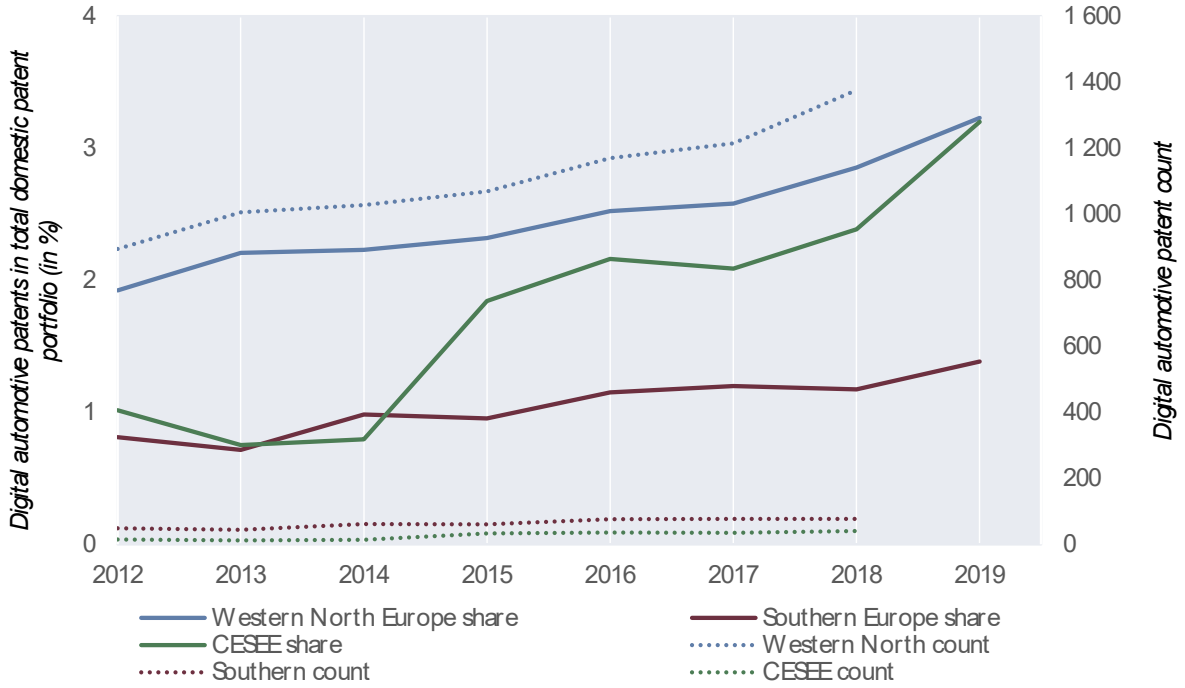
Note: The classification of "green" domains is broadly based upon the methodology of Haščič and Migotto (2015).
Source: Authors' calculations based upon PATSTAT (PCT) data in collaboration with ECOOM (Centre for R&D Monitoring, Leuven, Belgium).

Although it lags behind in most digital domains, vehicle-related digital patents are particularly important for Europe. There, Europe takes a clear leading role, both in absolute (patent count) and relative (share of patents related to vehicles over total patents) terms. Both green technologies themselves and the digitalisation of the automotive sector are integral parts of the European Green Deal. Even before the deal was announced, the European Commission had pinpointed digitalisation in

transport as a key priority. While CESEE countries do not hold a large number of digital patents overall, they have increased their relative presence in technologies covering both the transportation and digital sectors. As Chart 45 suggests, there is a remarkable trend in digital-automotive patenting activity (patents covering both the transportation and digital technological fields) in the region.

Chart 45

Digital patents: Percentage share and number



Note: The classification of "digital" domains is broadly based upon the methodology of EPO (2017).
Source: Authors' calculations based upon PATSTAT (PCT) data in collaboration with ECOOM.

Overall, CESEE countries have a strong relative presence in innovation in the automotive sector. The region engages in cutting-edge research, development and innovation in addition to basic car assembly and part manufacturing. However, the large players in Western and Northern Europe clearly remain the technological leaders (in terms of patenting activity) in digital-automotive technologies.

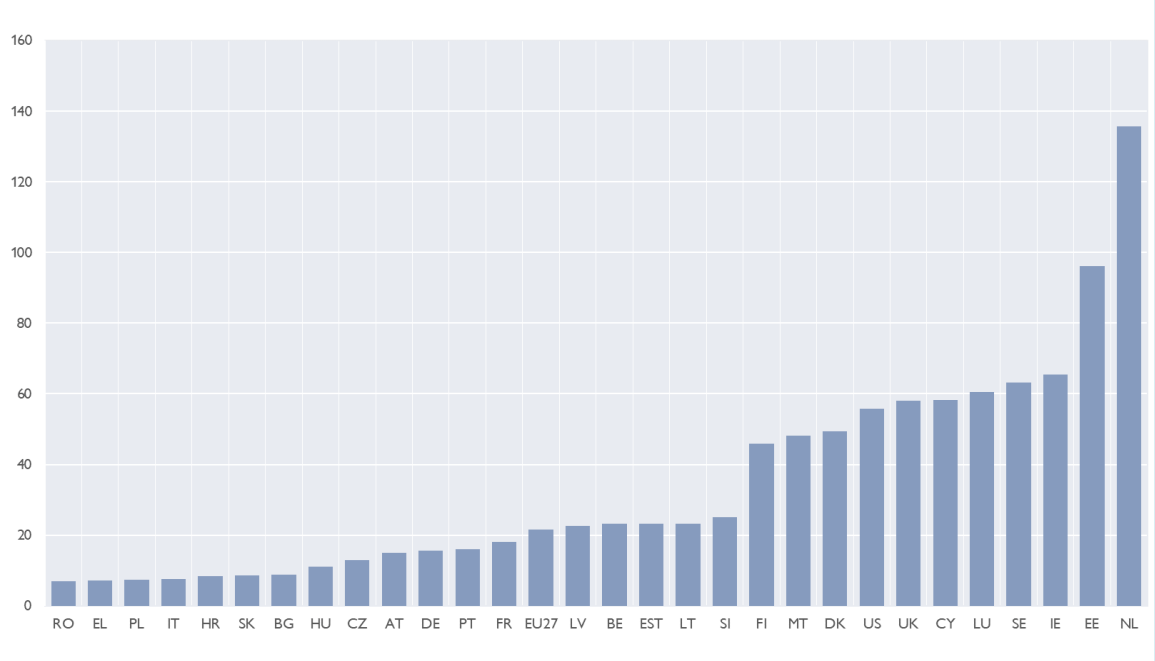
BOX 3: Startups in the automotive sector

Startups and scale-ups play an important role in fostering innovation. With climate change at the top of the political agenda, innovations and technological options for zero or low emission energy technologies are needed.

The CESEE region has, in general, a low startup and scale-up density[31]. This is true in absolute numbers and as a share of the total population (see Chart 46). Estonia is an exception, with a higher startup and scale-up density than the United States.

Chart 46

Startups and scale-ups per 100 000 inhabitants



Source: Crunchbase; author's calculation. Base: Firms founded between January 2008 and June 2021 that are still active.

The European Union has fewer automotive sector startups and scale-ups than the United States (see Chart 47). However, the share of startups in the automotive sector is higher in the European Union than in the United States, and is highest in the CESEE region (see Chart 48).

[31] This section draws upon data from Crunchbase, a commercial database on innovative firms seeking finance. The database is increasingly used by the venture capital industry and is a rich source of information on startups and scale-ups (see EIB 2019 for a discussion of its representativeness). Among other things, it offers the possibility to assess startups active in the automotive sector in more detail. There can be some lag between the foundation of a firm and its inclusion in Crunchbase. For this reason, the evolution of startup rates in the automotive sector as a whole is difficult to assess. However, the data on shares of different categories of startups can be interpreted in a meaningful way.

Chart 47

Number of startups in the automotive sector

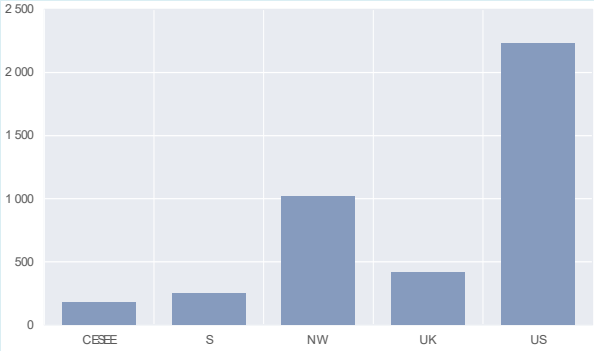
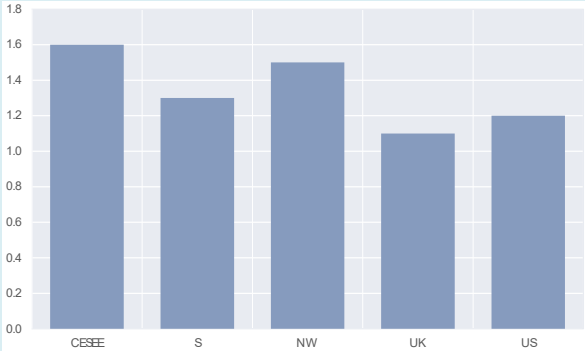


Chart 48

Share of startups in the automotive sector (%)



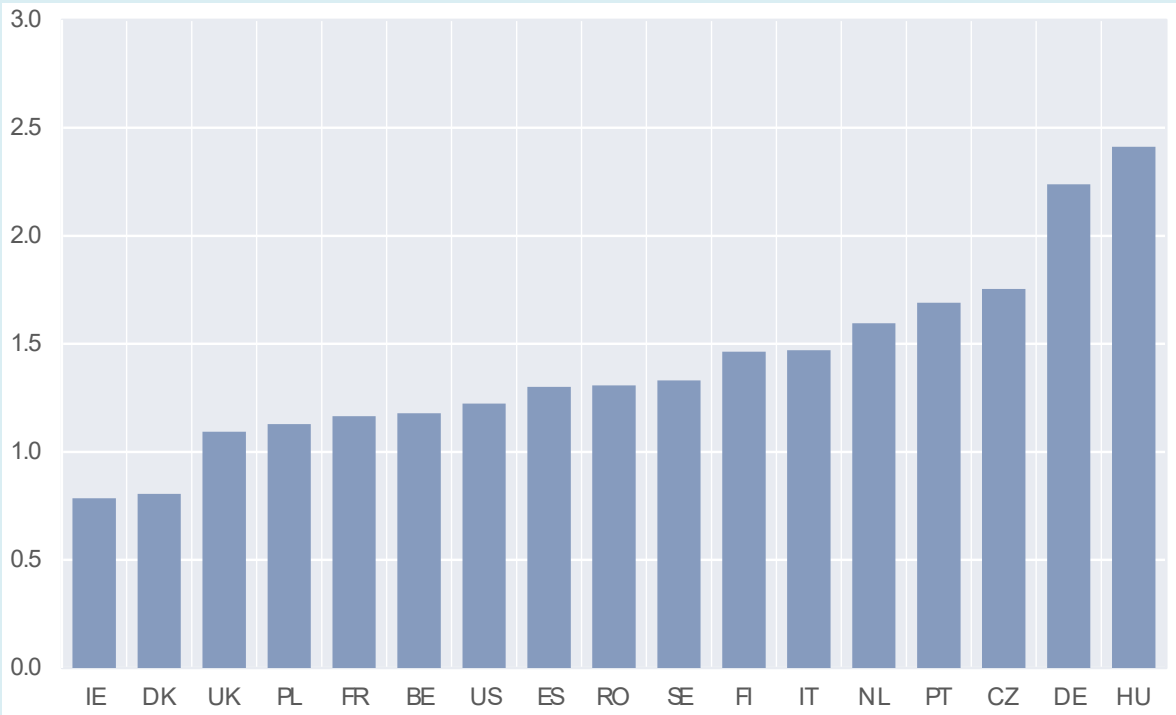
Note: CESEE: Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia. S (South Europe): Cyprus, Greece, Italy, Malta, Portugal and Spain. NW (Western North Europe): Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Luxembourg, the Netherlands and Sweden.

Source: Crunchbase, Eurostat, US Census Bureau, authors' calculation.
Base: Firms founded between January 2008 and June 2021 that are still active in the automotive sector.

There is considerable heterogeneity in the country-level data. Only Hungary and Germany have shares of automotive startups in total startups greater than 2%, while for other countries the share is markedly lower (see Chart 49).

Chart 49

Share of automotive startups, by country (in %)



Note: Countries with less than 20 automotive startups are excluded from this chart.

Source: Crunchbase; author's calculation.
Base: Firms founded between January 2008 and June 2021 that are still active.

One major disadvantage startups in CESEE face when it comes to scaling up their business is finance. The region has a notable gap in startup funding. The median amount of growth funding for startups in the automotive sector is higher than for startups overall in all regions covered, except for CESEE startups (see Chart 50). Here, automotive startups raised less funding than their peers in other sectors. In addition, the mean funding of automotive startups in the region was only 10% of the average amount of funding raised by automotive startups in Western and Northern Europe (see Chart 51).

Chart 50

Funding of startups, by region: Median funding automotive relative to all

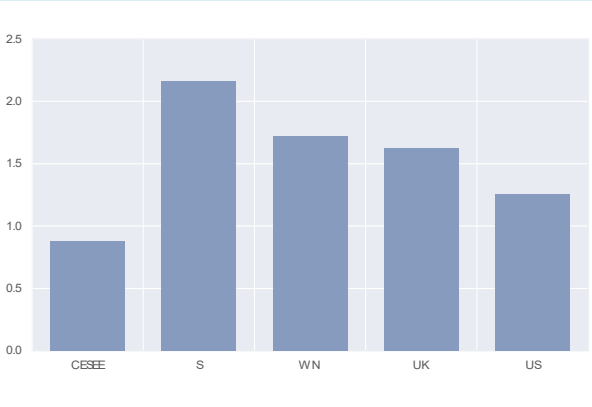
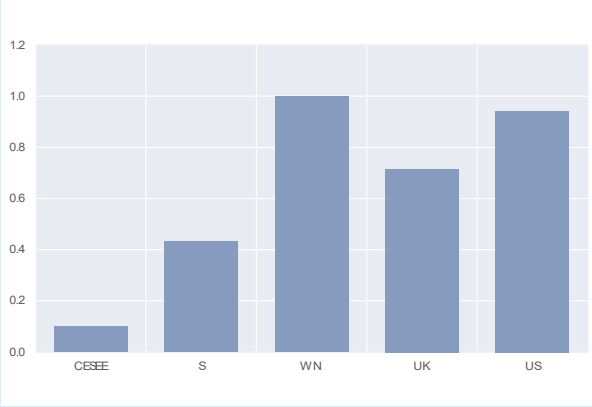


Chart 51

Funding of startups, by region: Median funding by region relative to Western and Northern Europe



Note: CESEE: Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia. S (South Europe): Cyprus, Greece, Italy, Malta, Portugal and Spain. WN (Western North Europe): Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Luxembourg, the Netherlands and Sweden.

Source: Crunchbase, authors' calculation. Base: Firms founded between January 2008 and June 2021 that are still active and that raised funding.

3 Transforming the sector: Investing and financing the transition

The automotive sector invests over EUR 170 billion a year worldwide[32]. Investments grew at an average rate of 1.4% between 2015 and 2019, while sales rose at an annual rate of 2.8%, reaching EUR 2.7 trillion in 2019 (see Chart 52 and Chart 53). Profitability is relatively low: as a percentage of sales, profits in automotive sector remained below 6% in recent years. In contrast, non-manufacturing sectors on average generate profits of close to 10% of sales.

Chart 52

Total major automaker sales (EUR billion)

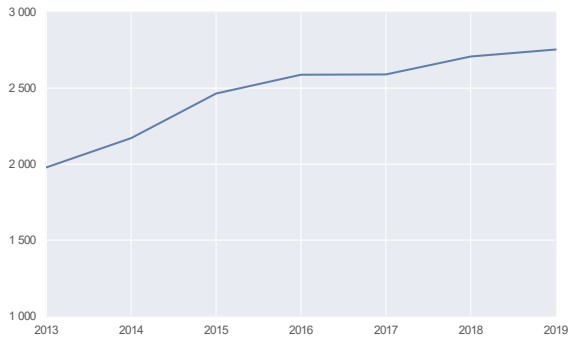
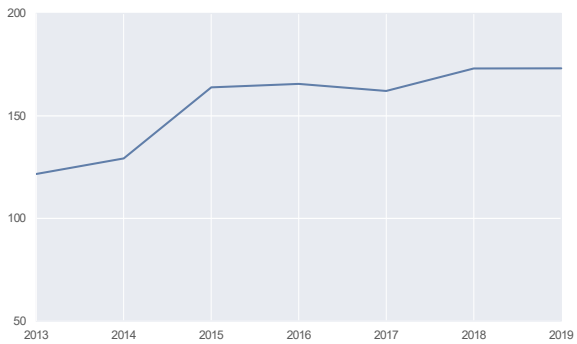


Chart 53

Total major automaker investments (EUR billion)



Note: The JRC analyses the 2 500 companies investing the largest sums in R&D in the world

Source: EIB calculations based on JRC EU Industrial R&D Investment Scoreboard.

Investment rates in the CESEE automotive sector[33] have remained very high over the past 20 years as a share of gross value added.[34] They have been significantly higher than those of firms in the same sector in the rest of the European Union (see Chart 54) and higher than those of industrial firms both in CESEE and in the rest of the European Union (see Chart 55).

[32] In terms of Capex. Source: JRC EU Industrial R&D Investment Scoreboard, which includes the main automakers and main suppliers. Latest data is from 2019.

[33] Automotive firms in this study are those firms whose main activity is classified in section C29 of NACE Rev. 2. In non-auto heavy manufacturing, we include Electricity, gas, steam and air conditioning supply (D35), Manufacture of basic metals (C24), of electrical equipment (C27), of fabricated metal products (C25), of machinery and equipment (C28), and of other transport equipment (C30).

[34] Investment rate in this chapter is understood to be the ratio of gross fixed capital formation, or investment, and gross value added.

Chart 54

Total gross fixed capital formation, % of gross value added — automotive sector

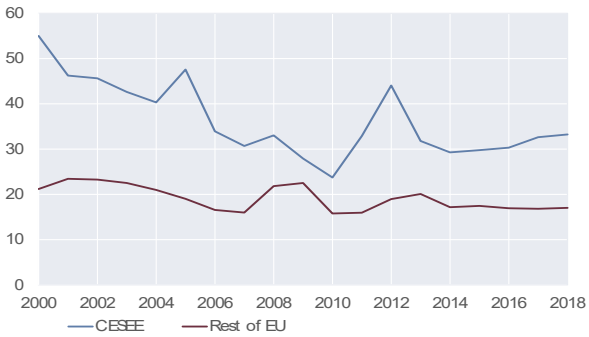
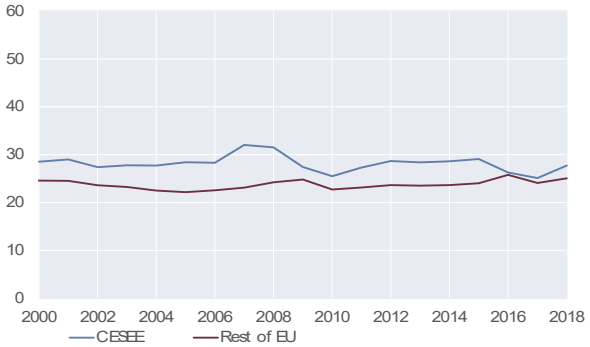


Chart 55

Total gross fixed capital formation, % of gross value added — total industry



Notes: CESEE: Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia. Rest of EU: Austria, Belgium, Cyprus, Denmark, Germany, Greece, Ireland, Finland, France, Italy, the Netherlands, Portugal, Spain and Sweden. Total industry comprises NACE rev. 2 sections B to E, excluding F (Construction).

Source: Eurostat National accounts.

The high investment rate of automotive firms in the CESEE region is the result of the decision of Western European automotive firms to shift the assembly of cars destined for the European market to CESEE countries. These large firms set up regional subsidiaries whose activity caused a proliferation of local suppliers, many of which are small and medium-sized enterprises (SMEs). As a result, investment in the automotive sector in those countries boomed in the late 1990s and the early 2000s (see Chart 54). With a view to better understanding these developments and drawing lessons for the future, we performed an in-depth analysis of this investment activity using a rich firm-level dataset: the European Investment Bank's Investment Survey.

3.1 A deep dive into the European automotive sector with the EIB Investment Survey

The EIB Investment Survey (EIBIS) facilitates a relatively detailed analysis of the investment activity of the EU automotive sector[35]. Using EIBIS matched with firm-level data from balance sheets and income statements, we can construct a sample of automotive firms from the European Union. This enables us to document the structural features of the CESEE automotive sector that shed light on its competitiveness and ability to successfully undergo the transition to a low-carbon economy. In order to put the characteristics of the automotive sector in the region into perspective, we compare it with two peer groups: automotive firms in the rest of the European Union and firms from other heavy industries in CESEE. Our sample contains 143 automotive firms from countries in CESEE, 150 Western European automotive firms resident in EU countries or the United Kingdom, and 1 206 heavy

[35] EIBIS is an EU-wide survey that gathers qualitative and quantitative information on investment activities by small and medium-sized businesses and larger corporates, their financing requirements and the difficulties they face. The survey covers approximately 12 000 firms across the EU27, 600 in the United Kingdom and 800 firms in the United States (the survey covers the United States only in the last two waves, which results in a rather small sample of US automotive firms. We, therefore, omit observations from the United States from our analysis). It covers a wide spectrum of questions on corporate investment and investment finance. The survey's responses provide a wealth of unique information about firms' investment decisions and their investment finance choices.

manufacturing firms from CESEE. These firms were interviewed from 2015 to 2019 in five waves of the EIBIS, some more than once (see Table 5).

The typical automotive firm in CESEE is a foreign-owned manufacturer of automotive parts or components. All firms in our sample have more than 50 employees, and about half of them have more than 250 employees. About 80% of firms from CESEE and about 60% of firms in the rest of the European Union and the United Kingdom supply automotive parts and components to car producers. Firms originate mostly from the countries that are most active in the automotive industry[36]. Furthermore, most of the firms in our sample are subsidiaries — around three-quarters in the CESEE region and two-thirds in the rest of the European Union — and most of the CESEE subsidiaries are foreign-owned. In the rest of the European Union and the United Kingdom, this share is about 50%. Almost all companies in the sample export their products to other countries.

Table 5

Sample size by region and number of occurrences

Number of times a firm participated in the survey	CESEE auto	Western Europe auto	CESEE non-auto heavy manufacturing	Total
1	99	95	762	956
2	29	31	273	333
3	9	13	121	143
4	6	7	41	54
5	0	4	22	26
Total	143	150	1.219	1.512

Source: EIBIS 2015-19 and EIB staff calculations.

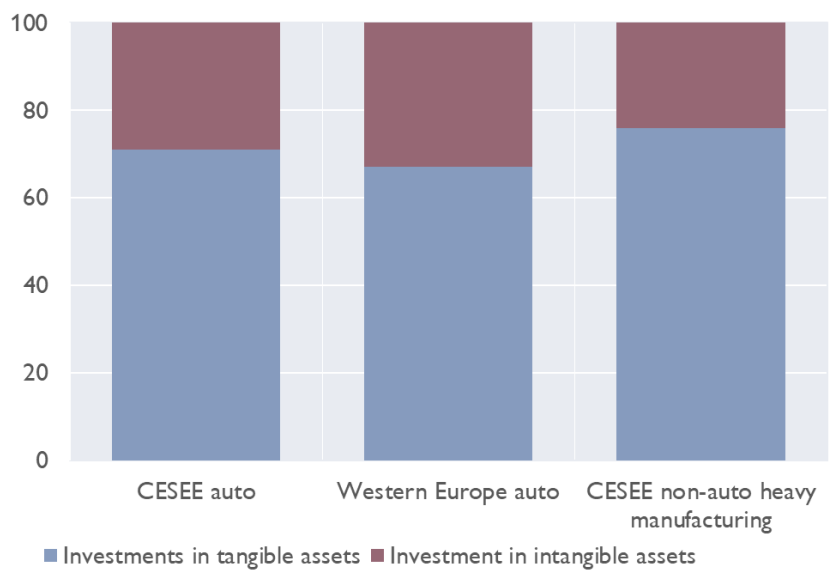
Automotive firms invest mostly in machinery and equipment. Automotive firms invest about two-thirds of their funds in tangible assets (see Chart 56). With just over 50%, machinery and equipment takes the largest share of investment. The second biggest investment category is land and buildings, with about 10-15% of total investment spending. Intangible assets such as capitalised R&D expenditure and software and patents account for about a third of investment expenditure.

Automotive firms in CESEE invest less in intangible assets than automotive firms in the rest of the European Union. However, automotive firms in the region invest more in intangibles than their peers in other heavy industries. Intangible assets are gaining importance in the modern economy as they are associated with higher productivity and innovation. They are thus linked to firm competitiveness.

[36] In Central, Eastern and South-Eastern Europe, these are the Czech Republic, Hungary, Slovakia, Poland, Romania and Slovenia (see Table 5).

Chart 56

Composition of investment into tangible (land, buildings and equipment) and non-tangible assets



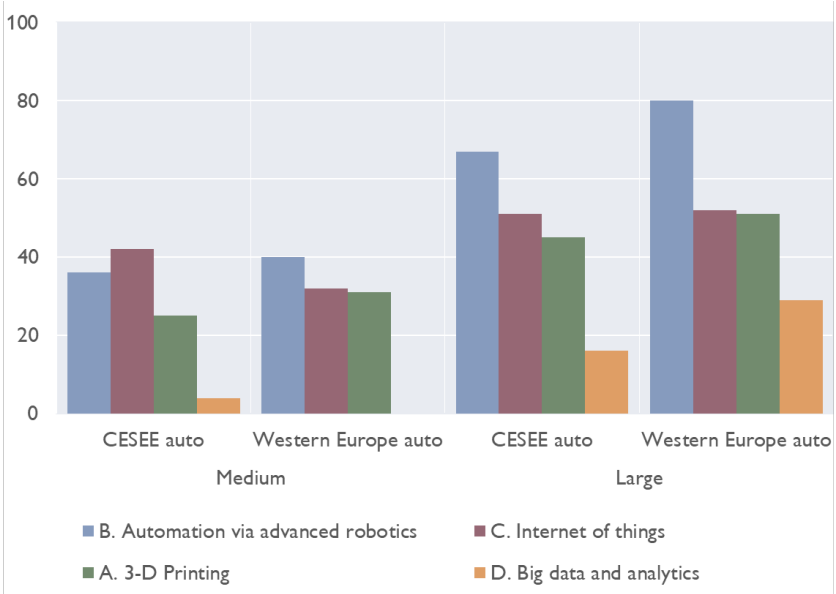
Q13: How much did your business invest in each of the following with the intention of maintaining or increasing your company's future earnings?
A. Land, business buildings and infrastructure; B. Machinery and equipment; C. Research and Development (including the acquisition of intellectual property); D. Software, data, IT networks and website activities; E. Training of employees; F. Organisation and business process improvements.
Notes: Investment in tangible assets is the sum of the investment shares in A and B. Investment in intangible assets is the residual.

Source: EIBIS 2016-20 and EIB staff calculations.

Automotive firms innovate and make substantial use of digital technologies, especially those more related with manufacturing processes, for instance in advanced robotics. About half of the automotive companies in our sample have developed or introduced new products or services. Three-quarters have organised at least some of their business around digital technologies. The most common digital technology among automotive firms is advanced robotics. In this respect, automotive firms from CESEE do not differ from their peers in the rest of the European Union. There are also no significant differences between subsidiaries and independent firms. These observations point to similar technological levels across countries and within multinational firms. That said, there are differences across size classes — large firms, which are less common in CESEE, innovate more and tend to make more use of digital technologies and other intangible assets (see Chart 57). Innovation is persistent: automotive firms that have been innovative in previous years tend to be innovative again.

Chart 57

Use of digital technologies



Q42c: Can you tell me for each of the following digital technologies if you have heard about them, not heard about them, implemented them in parts of your business, or whether your entire business is organised around them?
Notes: Shown is the sum of the shares of "Implemented in parts of your business" + "Organised entire business around it", in per cent.

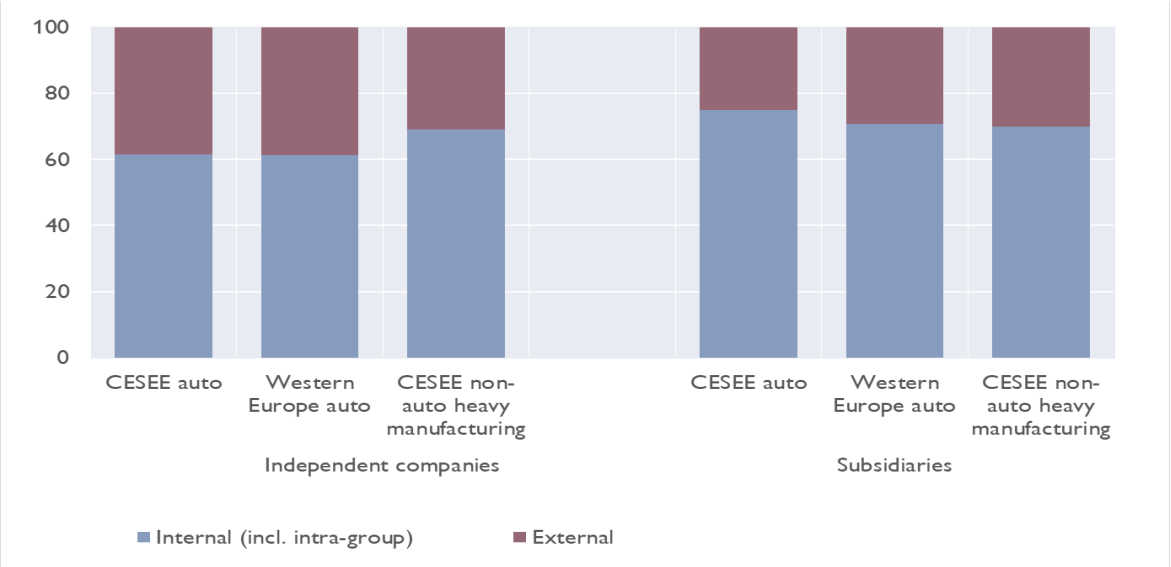
Source: EIBIS 2016-20 and EIB staff calculations.

Automotive companies finance their investment largely from internal sources. About two-thirds of investment finance comes from own funds and the rest comes from external finance. These shares are similar across EU firms in the automotive industry, and are also similar to the EU average for non-financial firms. Some differences exist across ownership structures, however. For independent companies in CESEE, the share of external funding is about a third (see Chart 58). For subsidiaries, which also have access to intra-group funding, it falls to about a quarter.

The structure of external investment finance differs between firms in CESEE and the rest of the European Union. Automotive firms in our sample source about two-thirds of their external finance in the form of bank loans, and a quarter from leasing or factoring. For the remainder, grants are a significant source of funding for CESEE firms, while some Western European automotive firms also issue bonds (see Chart 59). The higher use of grants in CESEE is most likely related to more common eligibility for European Structural and Cohesion Funds (ESIF), while the bigger size and more developed financial markets explain the higher share of bond issuance in the rest of the European Union.

Chart 58

Composition of investment financing



Q27: Approximately what proportion of your investment was financed by each of the following?

A. Internal funds or retained earnings (e.g. cash, profits)

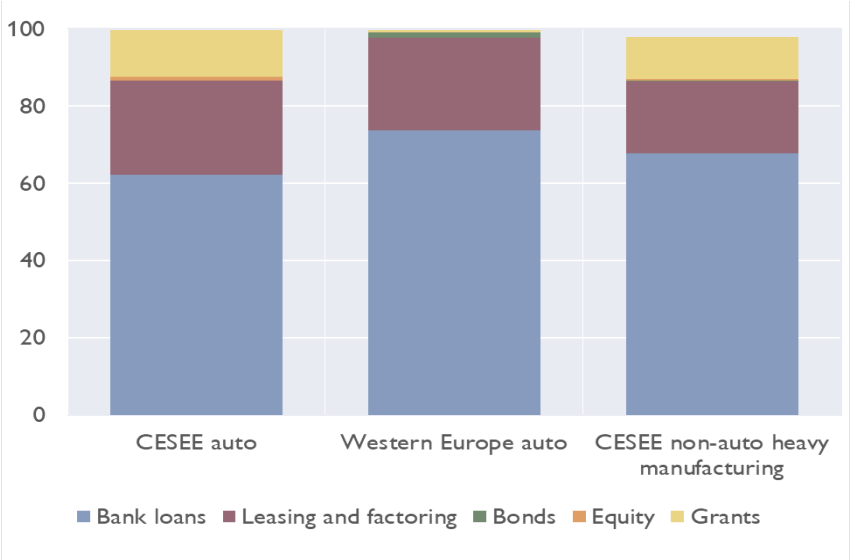
B. External Finance (e.g. financing from banks, private or public equity)

C. SUBSIDIARIES ONLY Intra-group Funding e.g. Loan from parent company

Source: EIBIS 2016-20.

Chart 59

Type of external financing



Q29: Approximately what proportion of your external finance does each of the following represent?

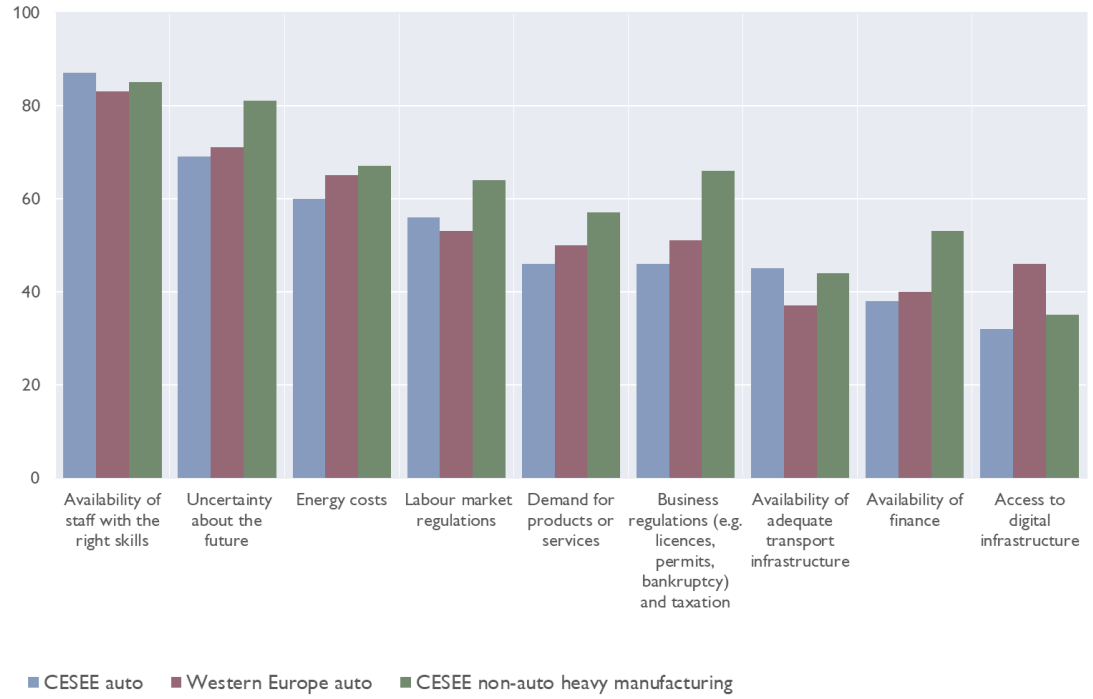
Notes: Omitted category — loans from business partners and family.

Source: EIBIS 2016-20 and EIB staff calculations.

A lack of suitably qualified staff and uncertainty are the largest investment barriers. This holds true for both manufacturing firms in general and CESEE automotive firms in particular. Inadequate infrastructure poses somewhat more significant investment hurdles for CESEE automotive firms than for Western European automotive firms (see Chart 60). Adequate infrastructure is therefore an important feature to take into account in the assessment of competitiveness and the ability of firms to adjust to the challenges of the green transition[37].

Chart 60

Investment barriers



Q38: Thinking about your investment activities, to what extent is each of the following an obstacle? Is a major obstacle, a minor obstacle or not an obstacle at all? Shown is the sum of the shares of "a major obstacle" + "a minor obstacle"

Source: EIBIS 2016-20.

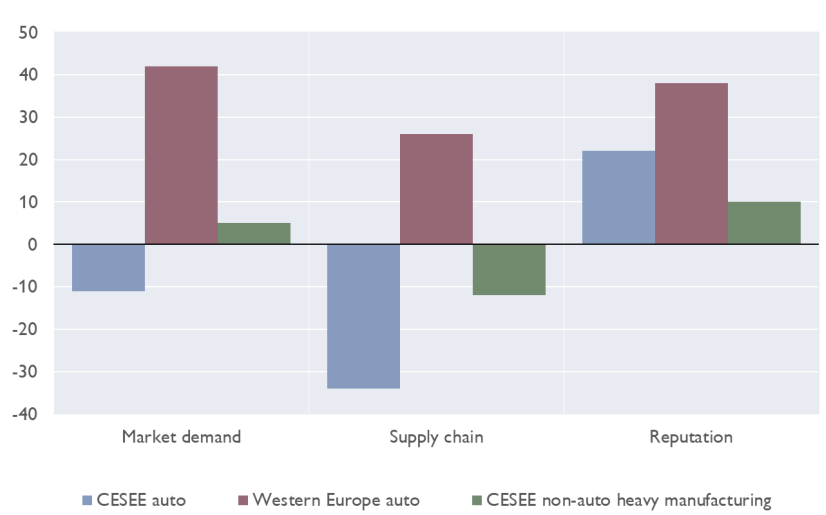
[37] To this end, it is important to remember that firms' responses reflect their production technology, their product portfolio, and their ambitions. They are not an objective measure of the quality of infrastructure. For example, the responses suggest that transport infrastructure appears more of a hurdle for CESEE auto firms than for their Western European peers, while the opposite is true for digital infrastructure. This does not necessarily mean that digital infrastructure is better in CESEE countries than in the rest of Europe, and that transport infrastructure is worse. It could equally mean that firms that are located in CESEE are less dependent on digital infrastructure and more dependent on transport infrastructure.

3.2 The green transition

Climate change mitigation policies are having a substantial effect on the automotive industry. Most firms believe the transition towards more sustainable business may have a negative impact on demand and supply chains over the next five years, while their reputation might benefit, according to EIBIS. CESEE auto firms are more pessimistic than auto firms in the rest of the European Union, but also than their peers in heavy industries (see Chart 61). This pessimism probably derives from the fact that the automotive sector in CESEE is dominated by suppliers that are not as innovative and are more financially constrained than their peers in the rest of the European Union. Furthermore, their path to the climate transition means that they should not only reduce their production emissions, but also change, in some cases significantly, their product line and business strategy.

Chart 61

Impact of the climate transition over the next five years



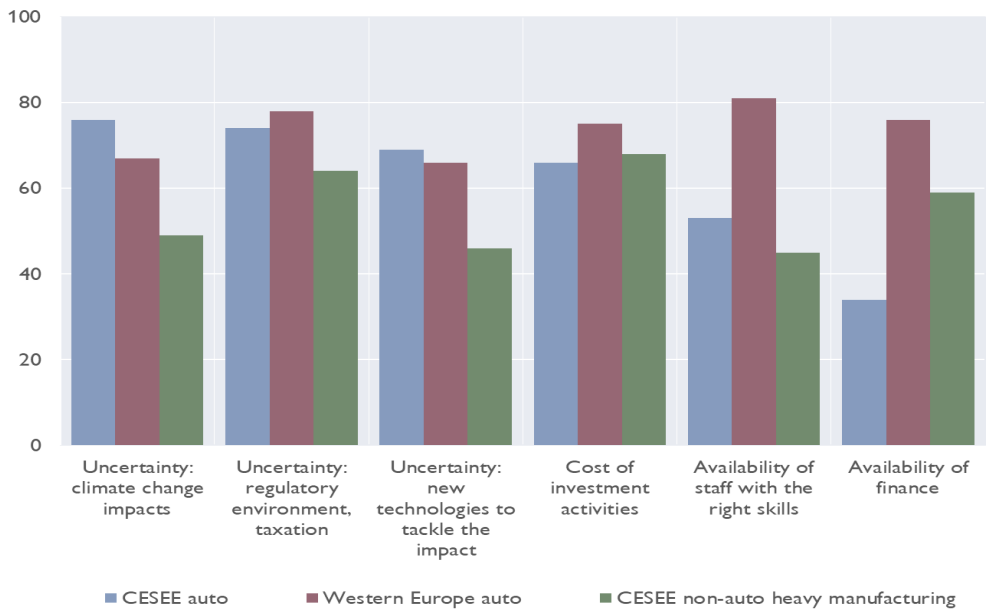
Q58: What impact, if any, will this transition to a reduction in carbon emissions have on the following aspects of your business over the next five years?
Notes: Shown are balances: share of responses "positive impact" net of share of responses "negative impact", in per cent.

Source: EIBIS 2020.

Uncertainty about technology, impact and regulations pose the highest barriers to investment in climate change mitigation and adaptation for the CESEE automotive sector. By 2019, about half of firms in Europe had already invested into mitigating the impact of climate change on their business. CESEE auto firms are somewhat less likely to have invested in climate change mitigation than in the rest of the European Union and they are less likely to plan such investment, being held back mainly by uncertainty regarding technology, impact and regulations. In contrast, Western European auto firms cite investment costs as the highest barrier (see Chart 62).

Chart 62

Barriers to investment in climate change mitigation



Q60: To what extent, if at all, is each of the following an obstacle to investing in activities to tackle the impacts of weather events and emissions reduction?
Notes: Shown is the sum of the shares of "a major obstacle" + "a minor obstacle", in per cent. This question was asked only in 2020 and therefore the sample is smaller.

Source: EIBIS 2020.

BOX 4: The EU Recovery and Resilience Facility and the green transformation: Less spending on automotive in CESEE countries

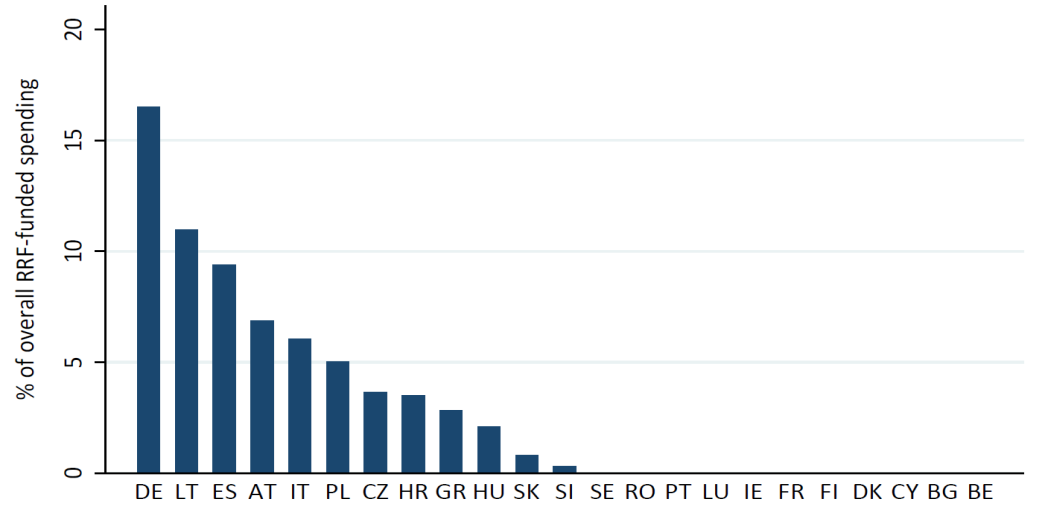
The Recovery and Resilience Facility (RRF) is the cornerstone of the European Union's financial support for Member States' economic recovery. The aim is to "build back better": the Recovery and Resilience Facility aims to fund in particular investments in the green and digital transformation. The support will be provided between 2021 and 2027, largely in the form of grants (EUR 338 billion in total at EU level) with some Member States also intending to borrow from the facility (EUR 166 billion in total). Member States with a lower GDP per capita, higher unemployment and greater impact from pandemic are eligible to receive higher grants.

A significant share of RRF funds target the transport sector. CESEE EU countries tend to spend between 10 and 20% of their RRF funds on rail, rolling stock, and road infrastructure. This is somewhat more, in relative terms, than the mostly richer countries in the rest of the European Union. Some Member States also allocate RRF funds specifically to the automotive sector. These allocations are particularly large in countries with large automotive sectors, such as Spain, Austria, Italy and Germany (see Chart 63).

The aim is to develop or market alternative fuel-powered cars (to substitute internal combustion engine cars) to advance the green transition of the economy. Many countries also intend to use RRF funds to build the required supporting infrastructure — in particular for charging vehicles — to trigger investment in climate-friendly transportation in the private sector. In absolute terms, Italy's dedicated automotive spending of EUR 11.6 billion is by far the largest, followed by Spain (EUR 6.4 billion) and Germany (EUR 4.5 billion).

Chart 63

RRF-funded spending dedicated to the automotive sector



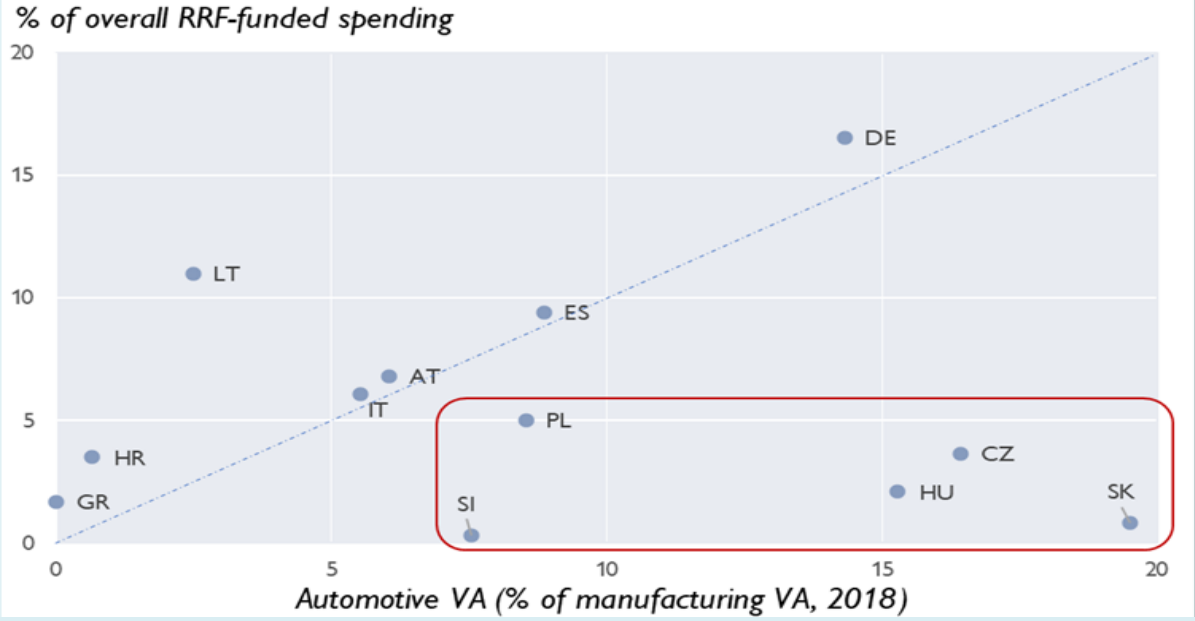
Note: Includes spending on electric vehicle purchase incentives and charging stations. Excludes spending on road. Based on RRP classifications as of June 2021.

Source: Eurostat, National Recovery and Resilience Plans, EIB.

CESEE countries allocate relatively small shares of their RRF funds to automotive and supporting infrastructure. No CESEE country is allocating more than 5% of their Recovery and Resilience Facility funds to the automotive sector, even though the sector accounts for more than 15% of national value added in some cases (for Slovakia, the Czech Republic and Hungary — see Chart 64). In most other EU countries with large automotive sectors these shares are larger — between 5% and 10% in Spain, Austria and Italy, and close to 20% in Germany — and tend to increase with the automotive sector's economic importance.

Chart 64

Dedicated RRF-funded spending on automotive is relatively low in CESEE



Source: Eurostat, National Recovery and Resilience Plans, EIB.

4 Implications, risks and opportunities

Massive changes in the automotive industry are set to bring about a new era with far-reaching but also partially unpredictable consequences, challenges, risks and opportunities. All the big trends in the automotive industry — from shared and connected to autonomous and electrified driving (see Chapter 1.2) — will come with massive economic, social and political implications. This holds particularly true for the unprecedented shift from a medium that has been the driving force behind our mobility for more than 120 years (oil) to electricity, within only a few years or decades. The next section takes a closer look at the consequences of these changes not only for the car industry itself, but also for some of the key macroeconomic and strategic variables. A particular focus will be placed on electrification, which is the most visible and advanced of the structural trends and also most likely that with the most significant impact on production, employment, consumption patterns and the environment.

4.1 The impact of electrification on the automotive industry[38]

4.1.1 Production processes and geography

The automotive supply chain will need to adapt to the transformation, and the current structure and geographical distribution of activities will likely change. To cope with its ongoing transformation and the important shift driven by vehicle electrification, the automotive industry needs further development of innovative electric powertrain and battery technologies, together with accelerated change and adaptation in its entire supply chain (in terms of technology and production capacity, skills and abilities) and the rapid build-up of a competitive domestic battery manufacturing base. Given the important role of batteries in electric vehicles, their share of cost and weight, the difficulty of shipping batteries to distant destinations, and the need to ensure a smooth and flexible just-in-time automotive supply chain, a certain level of (regional) proximity between cell manufacturing, battery module and pack assembly and electric vehicle assembly will become a requirement for the future of a competitive automotive industry.

Proximity to electric vehicle assembly facilities will continue to be a factor in deciding where to locate new battery factories in Europe. The geography of battery cell production is set to become a key element in determining the preservation and transformation of car industry production and employment in Europe, and in particular in the CESEE region. Given its political and economic relevance, many countries in Europe are therefore already acting to support and incentivise placing cell and/or battery production plants close to their automotive manufacturing clusters to avoid the risk of future downsizing. This can be seen in European battery cell production projects that have already been implemented, are under implementation or have just been announced (see Chart 65). While local battery cell production will be crucial for the future preservation of car assembly, the highly automated nature of battery cell manufacturing itself means that it will have a rather limited impact on employment. This is because a battery cell manufactured in Europe captures a maximum of 30% of the value creation potential, with the rest being made up by raw materials.

[38] This sub-chapter intends to put together hypotheses and sketch out a scenario of how electrification may impact the automotive market and its supply chains. Although the authors believe that this is a likely outlook, it is of course still highly speculative.

Chart 65

Battery cell manufacturing projects in Europe (operating, under implementation, announced)

Source: EIB analysis of multiple sources; illustrative chart, non-exhaustive, based on cell battery plants in operation, projects under implementation or announced.

As the momentum for electrification gathers pace, the geographical distribution of auto manufacturing has already been impacted. There is growing evidence of a polarisation of electric vehicle production in some European countries. Given Germany's role in the automotive sector and the strategy announced by German automakers, the country may emerge as the centre of a battery electric vehicle production core. German vehicle output has been on a downward trend since 2018, but investment in battery electric vehicles remains, at least in this first phase, closer to home. To some degree, this is also mirrored in France, where key battery electric sourcing decisions are staying local. The situation is still quite fluid and subject to change. However, the ongoing and planned allocation of battery electric vehicle production programmes to car plants and the location of (cell) battery manufacturing will clearly influence one other and play an even stronger role in the future.

Vehicle electrification will also affect current roles and the level of control the different industrial players have over upstream and downstream activities. Major automakers in particular may lose some of their prominence and power, and could end up transferring the control of larger parts of the vehicle value adding stages to suppliers and partner firms, which are often new entrants to the

industry. As mentioned above, this is particularly associated with big tech companies in the domains of automation and connectivity, but it can also be seen for electric technologies. Some upstream suppliers could become completely displaced (for example those associated with ancillary technologies and components for the internal combustion engine and its powertrain) if they do not master other technologies still relevant for the automotive industry of the future. Other suppliers will not be directly affected by the electrification shift (for example those delivering interior and exterior components or tyres, etc.), whereas some (including new entrants) could increase their importance (for example suppliers connected to electric and electronic technologies, those providing advanced vehicle safety and driver-assistance technologies, etc.). Manufacturing activities in general — and related employment — could take a hit, as electric vehicles mostly require simpler assembly processes, fewer and very different parts, and a larger share of electric and electronic components than mechanical components.

4.1.2 Impact on the supply and demand side of the car market

With electrification already overhauling the industry's production processes, the next question concerns how electric vehicles will affect the demand side of the car market. As discussed above, there seems to be a strong consensus among the major players driving the structural shift towards electrification that the combustion engine will be replaced by electric vehicles very soon. Moreover, it is widely believed that with the necessary incentives, support and regulations, electrification will proceed quickly. However, straightforward projections of how many electric vehicles need to be sold to meet carbon emission targets (in different scenarios) are not necessarily indicative of the future relationship between supply and demand. The next section attempts to disentangle some of these factors and sketch out a possible scenario in a qualitative manner.

As electric vehicles continue to improve and become more competitive, their prices and profit margins are projected to converge with those of their internal combustion engine counterparts. Assuming that battery prices continue to fall and the cost of emissions-reducing technology for internal combustion engine vehicles continues to rise, the price of a low-range battery electric is widely expected to become comparable with an internal combustion engine vehicle. Longer-range battery electrics would become strong competitors in price to internal combustion engine vehicles by offering a similar range at a lower cost. However, if carmakers wish to achieve profit parity between the two vehicle types, decreasing battery costs will need to be accompanied by more strident adoption of manufacturing platforms that are fully dedicated to electric models to increase benefits related to economies of scale. This would make more efficient vehicle design and dedicated component sharing possible, increasing production scale, reducing costs over time and raising the margins of electric vehicles. Some major automakers (some Chinese automakers, Volkswagen Group, etc.) have already moved into dedicated electric vehicle platforms, whereas others still rely on shared internal combustion engine and electric vehicle platforms, increasing flexibility but helping less in terms of reducing production costs. Contract manufacturing could also play an important role for the manufacturing of electric vehicles, particularly for smaller carmakers or startups. Some contract manufacturers in Europe and in Asia (Tier 1 suppliers such as Magna and Foxconn) are indeed aiming to set up flexible contract electric platforms that would accelerate market deployment and bring economies of scale to smaller or new-entrant electric vehicle companies. The scale of production, shared platforms and decreasing battery costs for electric vehicles and the increasing cost of emissions-reducing technology for internal combustion engine vehicles are therefore largely expected to drive the achievement of profit parity between the two vehicle types in the coming years.

Price convergence will be driven both by falling prices for battery electrics and rising prices for internal combustion engine vehicles. Research, development and production costs for conventional cars are rising significantly in the wake of the ever-stricter safety and emission regulations. Higher costs are, of course, subsequently reflected in mounting end-consumer prices. Such price hikes will be particularly noticeable in the smaller cars segment, where carmakers' margins were already rather limited.

The supply variety of internal combustion engine vehicles is progressively narrowing as choices vanish from the market. The effect of ever-stricter emission regulations on the supply side of the car market can be illustrated by the recent example of Skoda's Fabia Combi. It was announced in January 2021 that a new generation of Fabia Combis was on the way and would launch in 2023. However, at the end of August 2021 Skoda management had to revoke their plan to sell the new station wagon. The (sunk) research and development costs of the model had reportedly amounted to CZK 1 billion (about EUR 40 million). The direct underlying reason for the U-turn was that the car would simply become uneconomical in light of ever-stricter regulations. Apart from Euro 7, a paradoxical explanation for this is that small and light vehicles (with a comparatively low carbon track) — especially if they are popular on the market — tend to render major automakers' specific CO_2 targets stricter and thus increase (potential) CO_2 penalties for them[39]. However, the shrinking variety will not be limited to the models of fuel-driven cars available — supply diversity will also be impaired in other ways, such as on transmission options.

As internal combustion engine-related options wind down, the electric vehicle supply side will ramp up fast. The future fall in electric vehicle prices on the back of cheaper batteries and better economies of scale is widely expected, but producers also keep improving other key supply factors. Battery range (the mileage that can be travelled on a single charge) is rising at such a rate that by the end of 2021, battery electric models with an estimated maximum range (according to certified standards) of more than 800 km[40] became available on the market, and more such models are expected to arrive soon. The average battery capacity of battery electrics is projected to grow by 32% along with a 23% increase in energy density in the next decade. Most importantly, the number of electric models on sale is expected to skyrocket in the coming years. The number of battery electric models available on the European market surged from 26 in 2019 to 79 in 2021, according to LMC Automotive. Finally, the rising density of charging infrastructure will also significantly improve the electric vehicle supply side.

While the increasingly attractive supply side of the electric vehicle market will certainly stimulate demand, exact future uptake by consumers remains to be seen, at least in the short term. Future electric vehicle demand is expected to be spurred on by the factors detailed above, such as i) falling costs, improving driving ranges and life expectancy of batteries; ii) falling battery electric prices relative to comparable internal combustion engine vehicles; iii) increasing electric model variety; iv) widely available fast charging infrastructure; and v) more robust and predictable electric vehicle resale values. Yet in light of the above-mentioned trends, the question arises of when there will be an electric alternative with a comparable value-for-money ratio to the gradually vanishing fuel-driven options,

[39] This is because a major automaker's specific CO_2 emission target (SET in g CO_2/km) — which eventually determines the CO_2 penalty — accounts for its specific average fleet weight (m) relative to the reference weight m_{ref} (currently equal to 1 379.88 kg) according to the following formula: $SET=95+0.0333(m- m_{ref})$. As a result, the more small and light cars an automaker sells, the lower its average fleet weight relative to the reference weight, and thus the stricter the SET in g CO_2 per km of its fleet. (See Regulation (EC) No 443/2009 and Regulation (EU) 2019/631.) Skoda CEO Thomas Schäfer thus issued a warning that when Euro 7 is implemented, small cars (below EUR 20 000) are likely to vanish from the market, and automakers' investments in electrification are likely to be held back. ('The sub-£20k new car could vanish under Euro 7 eco rules' | Auto Express)

[40] Longest-range electric vehicles (EVs) you can buy in 2021 - Electrek

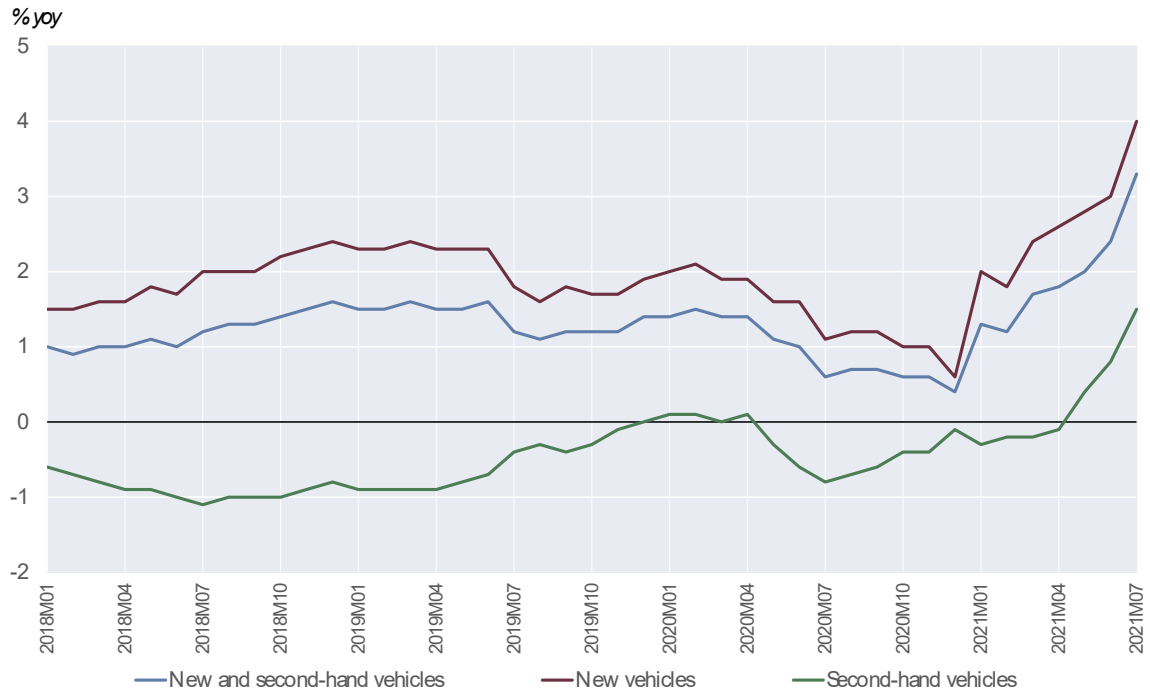
especially in the small and economical cars segment. To put it figuratively: will consumers currently in the market for such cars (such as the Skoda Fabia Combi) opt for a smaller internal combustion engine alternative, a bigger but more expensive model or a (probably even more expensive) electric vehicle? Will they decide not to buy a new car at all for the time being and stick to their existing old one for several more years? Or will they change their mobility patterns and switch away from individual mobility to public transport and/or car sharing? Large-scale acceptance of electric vehicles by consumers is likely to hinge on the value for money they will be able to offer relative to their internal combustion engine counterparts. In the 2020 Global Automotive Consumer Study by Deloitte (2020), 45% of consumers indicated that they were not willing to pay any more for an electric vehicle than for a similar petrol/diesel vehicle. However, it must be borne in mind that several factors other than price (for value) matter for consumers when considering electric vehicles. Access to charging facilities has been shown by several studies to be a particularly important driver of demand for electric vehicles[41]. However, in the United States, for example, less than half of vehicles have a dedicated parking space where a charger could be installed (Traut et al., 2013). According to the Deloitte (2020) study, only a third of consumers in Europe have access to a (more or less useful) charging outlet, in Eastern Europe the situation seems even worse. What also needs to be kept in mind is the changing profile of electric vehicle buyers over time — a factor that will likely impact demand. Early buyers (pioneers) differ significantly from (future) mainstream consumers with regard to their lifestyles, wealth, preferences, technology fervour and environmental considerations (Axsen et al., 2016). In a study on market acceptance for electric vehicles by consumers in China, Chen et al. (2021) examine the decision-making process under multi-policy scenarios. Generally, the authors find that consumers are caught in a state of "high attitude and cold behaviour", which means that they think positively about buying electric vehicles, but do not actually do so.

Overall, the structural overhaul of the automobile industry will render cars less affordable, at least during the transition period. While electric vehicles are expected to become cheaper than they are today, it is questionable whether/when they will ever reach the (real) price levels at which mainstream consumers can afford a car today. In addition, electric vehicles still need to become comparable with internal combustion engine vehicles in terms of as practical use (in particular, easy charging including for on-street parking, driving range, re-sell value, safety, etc.) in order to convince the mass-market consumer. As a result, some consumers who would under normal circumstances buy a new internal combustion engine car will not be able to (afford it). These consumers will thus either change (and thus face a massive setback to) their individual mobility habits — resorting more to public transport and working from office — stick to their old car, or buy a second-hand one. As a consequence, the prices of second-hand cars and the average car age may go up. Prices of both new and second-hand cars started to rise sharply in early 2021 (see Chart 66). Yet it is unclear at this stage to what extent this upward trend has been driven by the structural factors described above, and what role has been played by other (cyclical, temporary) factors, especially the ongoing semiconductor supply shortage, lower production, prioritisation of most expensive models, etc.

[41] See, for example, Chen et al. (2021) or Ma et al. (2020).

Chart 66

Annual price change of passenger cars in the European Union



Source: Eurostat.

In parallel, the average car age is set to go up at least in the short to medium term. The average age of cars in the European Union went up from about eight years in 2007 to approximately 11 years in 2020, with (significant) differences between old and new Member States. The net impact of contradictory factors (fewer new cars and an increasing share of new electric vehicles on the one hand vs. the trend towards bigger cars, more cars on the roads and ageing car stock on the other) on CO_2 tailpipe emissions during the transition remains to be seen[42].

[42] Moreover, tailpipe CO_2 emissions provide only a very partial indication of the carbon footprint as they do not capture the overall, rather complex CO_2 emission balance of different powertrain technologies over the entire life cycle of a car. See 4.2.3 for a more detailed discussion.

Chart 67

Average age of passenger cars in the European Union

Note: EU-10: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Portugal and Sweden since data for 2007 is available only for this subset of EU countries. EU-14: in addition to EU-10, also includes Ireland, Luxembourg, the Netherlands and Spain.
Source: ACEA, authors' calculations.

EU and national regulations are speeding up the transition. These regulatory standards do not always meet the preferences stated by market participants. Several high-level representatives from major automakers (such as Toyota and Stellantis) and the automotive industry in a broader sense (such as the European Association of Automotive Suppliers (CLEPA) and European Automobile Manufacturers' Association (ACEA)) have repeatedly called — in line with consumers' preferences — for an open approach to multiple parallel, competing technologies. The looming and increasingly evident discrepancy between CO_2 targets on the one hand and their impact on consumers on the other is likely to lead to political tensions.

4.2 Macroeconomic, (geo)political and environmental aspects and risks

4.2.1 Massive and risky infrastructure investment needs

a. Charging infrastructure

Immense investments in charging infrastructure are a necessary prerequisite for boosting large-scale electric vehicle demand. As outlined in the previous chapter, whether the mainly supply side-driven changes in the automotive market will also create sufficient demand in the near future is a key open question — one that is closely related to the availability of charging infrastructure. The (implicit) push towards electric vehicles involves considerable concentration risks that need to be factored into decisions not only by car producers but also by investors, banks, regulators and policy makers (Chen et al., 2021). Europe has trended towards charging stations so far, but an alternative would be changing entire batteries at battery swap stations as promoted, for example, by the Chinese company NIO. To ensure the provision of charging infrastructure, massive public and private investments in building, powering and maintaining charging stations are required. The IEA (2021b) estimates that in order to achieve the goal of carbon neutrality by 2050, the global number of public electric vehicle charging points has to rise from around 1 million today to 40 million in 2030, requiring annual investment of almost USD 90 billion until 2030. In addition, the number of private chargers would have to go up from 270 million in 2020 to 1.4 billion in 2030[43]. However, there is an important trade-off subject to high uncertainty. In research on the question of extended battery capacity vs. expansion of fast charging stations in Germany, Funke et al. (2019) come to the conclusion that investment needs measured in euros per battery electric vehicle are three to seven times lower when spent on fast charging expansion rather than battery capacity increases. This means that highly costly but unavoidable expansion of charging infrastructure remains subject not only to future technological risks but also to consumer preferences regarding the choice between cheaper vehicles requiring more frequent recharging on the one hand vs. more expensive alternatives with extended battery capacity on the other.

Besides the vast investment sum, the need for a dense network of charging stations will involve major demand for land, mainly within urban areas, to make the charging stations accessible to much of the population. While conventional petrol stations can quickly fulfil the energy needs with limited land use, charging stations must be scattered widely and in large numbers. These stations will also be occupied for longer, as even fast chargers need considerably more time to fuel a vehicle than petrol stations. This problem will be more acute in Europe and China, where less land is available and population density is higher (Hensley, Knupfer and Pinner, 2018)[44].

b. Electricity generation and transmission

Electricity generation and transmission is another area where huge investment needs are likely looming. In general, the additional energy demand by 2030 might not be as severe as some fear, while the demand for 2050 seems more challenging. Engel et al. (2018) forecast that, for the example of Germany, growing mobility electrification will not lead to significant increases in total electricity demand in the near to medium term. By 2030, electric vehicles will increase total power demand by 1%, which will rise to about 4% by 2050 compared to 2015. Similar results are used in a study by the

[43] Between 2030 and 2050, the number of public and private electric vehicle chargers would have to rise, respectively, from 40 million to 200 million and from 1.4 billion to 3.5 billion.

[44] The cost and space-intense investment in charging infrastructure poses the risk of an East-West divide in terms of transportation.

European Commission, in which Klettke and Moser (2018) aim to investigate the impact of increased electric vehicle use on the EU power system. The authors forecast passenger electric car penetration of about 35 million in 2030 and 190 million in 2050 for the former EU28 countries. This implies that by 2050 about a third of all final personal vehicle energy demand will be electric. This level will increase the electricity demand in the European Union by about 2% in 2030 and by 10% in 2050. Higher figures are obtained in an assessment by the European Environment Agency. The electricity demand necessary for electric vehicles to hold an 80% share of total vehicle numbers in 2050 ranges between 3% and 25% of total electricity demand per former EU28 country. On average, the additional share of electricity consumption by electric vehicles will be 4-5 percentage points higher in 2030, and 9.5 percentage points higher in 2050 than in 2014 (EEA, 2016). For the goal of CO_2 net-zero emissions by 2050, the IEA (2021b) sees global electricity demand for road transport rising to less than 2 000 TWh in 2030. About half of this will be due to electric passenger cars, whose number is likely to increase 18-fold compared to 2020, and thus amount to 60% of cars on the roads. Until 2050, electricity demand for road transport will increase to 11 000 TWh (some 4 000 TWh for cars and vans, 100% electric by then). The latter figure is projected to equal 15% of total electricity consumption, thus placing the estimate in the range that the European Environment Agency estimates for the former EU28 countries. On top of investment in power generation comes investment in transmission and distribution grids.

Additional energy demand aside, charging — and especially fast charging — might severely strain the peak load capacity of grids. Large-scale electric vehicle penetration will potentially change the electricity load curve and place a strain on the grid. An increase in evening peak loads can be expected when people plug in their vehicles after work. Studies estimate that the peak load increase in Germany will be about 1% by 2030 and approximately 5% by 2050. Moreover, electric vehicles will be more dominant in suburbs, thus leading to challenges for the load curve at the local level. In particular, residential areas and hot spots such as public fast charging stations and commercial vehicle depots will be confronted with increased local peak loads (Engel et al. (2018); Klettke and Moser (2018)). While it is difficult to disentangle which part of the investment need would be due to electric vehicles only, the IEA (2021b) estimates that for net-zero emissions, global investments in transmission grids need to expand from USD 260 billion annually today to USD 820 billion in 2030.

c. Batteries

Independent of established infrastructure for charging, investments in battery production capacities will be key to laying the groundwork for an electric vehicle-focused future. These infrastructure needs target battery production on the one hand and battery capacity on the other. The latter plays a special role in consumer demand, as range anxiety hinders more mainstream adoption of electric vehicles. Research by McKinsey estimates that for a shift from internal combustion engine vehicles to 75% electric vehicle sales by 2030, Europe needs to build additional 24 battery gigafactories just to supply the local passenger electric vehicle battery demand (Conzade et al., 2021). Globally, to reach the net-zero emissions goal, annual battery production needs to reach 6 600 GWh in 2030, which is equivalent to adding 20 gigafactories per year until 2030 (IEA, 2021).

A functioning and sustainable battery supply must comply with several criteria. As batteries make up 40% of the value of electric vehicles, they are a key input for the car producers' value chain. Ernst and Young defines five criteria enabling major automakers to establish a short and medium-term battery supply: first, cost competitiveness in battery production, due to the large contribution of batteries to the value of electric vehicles; second, technical performance of batteries; third, localisation of battery manufacturing to ensure availability of supply; fourth, compliance with rules of origin, as

non-compliance would trigger tariffs on batteries; and fifth, sustainability in battery manufacturing (Nicholson, Penney and Patel, 2021).

4.2.2 Global competition for scarce resources and inputs with ensuing geopolitical and ecological consequences

The global chip shortage might be the bellwether marking the beginning of a new era of reoccurring supply shortage risks. Changing consumer habits, supply chain disruptions, technological progress and regulatory decisions in areas such as the electrification of vehicles or autonomous driving pose challenges for the supply side of the car market. Increasing supply bottlenecks are part of these challenges, as they have caused significant strain on the electrification initiatives of many auto producers[45]. For most of 2021, the automobile industry worldwide suffered heavily from the semiconductor shortage and the supply bottleneck will not fade away quickly. As a result, car manufacturers have had to cut production significantly, in Europe by as much as 25% year-on-year[46]. Contributors to supply bottlenecks are the heavy reliance on Chinese imports for some elements of car production, backlogs in transportation due to port congestion and a lack of truck drivers. It remains to be seen what initiatives automakers will take to resolve the supply bottlenecks that they are facing and how they will act on becoming more resilient to supply chain backlogs. A key issue in this respect will be the supply of raw materials critical for mobility electrification.

Natural resources — some of which are scarce and will see intensifying global competition — are essential for the production of batteries and electric vehicles in general. A single average car lithium-ion battery pack contains around 8 kg of lithium, 35 kg of nickel, 20 kg of manganese and 14 kg of cobalt as well as other rare earth elements. The global move to electric vehicles has accelerated pre-existing fierce competition for these limited input resources (Subin, 2021). The IEA (2021b) estimates that demand for lithium for use in batteries will swell by a factor of 30 by 2030, for example, while demand for rare earth elements, used in particular for making electric vehicle motors and wind turbines, will expand by a factor of ten over the next decade. The booming demand for these metals will be met by constrained supply. This is largely due to the fact that opening up new mining operations is a long-term process with uncertain and volatile cash flows. Moreover, it is increasingly difficult to comply with environmental, social, governance (ESG) and other regulatory standards, which makes corporations and investors reluctant to take this risk (Bloch et al., 2018). In addition, there is considerable market concentration both on the side of companies active in the extractive and commodity trading industry such as BHB Billiton, Glencore, Rio Tinto, Trafigura and Vitol Group (Schneyer, 2011), as well as at country level. For example, China accounts for 65% of graphite, Indonesia supplies 50% of nickel and the Democratic Republic of Congo provides 65% of the global cobalt supply (Hellwig, 2018). Moreover, most cobalt mines in Congo are owned by Chinese companies. As a result, not only is the production of essential metals highly concentrated in a handful of countries, but China clearly also dominates their refining and processing[47]. In doing so, China simply

[45] https://www.nytimes.com/2021/10/15/business/toyota-november-production-chip-shortage.html

[46] Chip shortage: auto industry calls for more EU-made semiconductors - ACEA - European Automobile Manufacturers' Association

[47] The key question regarding the extraction of raw materials is not only the (potential) availability of deposits but also whether/when they can be economically (and in line with ESG standards) mined and processed and who controls these processes. Lithium, for example, is not rare per se. There are many reserves worldwide, the largest supposedly in Bolivia and Argentina. But due to technical, geographic and political challenges, these reserves remain largely undeveloped. This means that the largest producer of lithium by far worldwide is Australia, even though it ranks only fifth on the list of largest explored deposits. Moreover, extraction in Australia is to a large extent controlled by Chinese companies such as Tianqi Lithium and Ganfeng, from which Volkswagen sources its lithium, for example. Potentially large deposits of lithium are even present in

fulfils what it has announced as its objective — namely to dominate the world's emerging clean energy economy[48]. There are therefore clear monopolistic or oligopolistic tendencies in the raw materials market.

The excess demand for raw materials implies significant (geo)political, economic, environmental and social risks. For raw materials, the transition to electromobility will unavoidably involve a shift to higher dependency on a small group of (partially flawed or outright non-democratic) countries and/or firms in the future, replacing (or at least for some time coming in addition to) Europe's reliance on oil and gas in the fossil energy past. It remains to be seen whether or under what conditions the dominant (mostly Chinese) players will be willing to provide the key minerals to European car producers and to what extent they will instead prioritise the production of electric vehicles by their own companies, either in their home countries or directly in Europe[49]. These supply warnings come in many instances together with serious environmental and social concerns regarding the use of land, scarce water, corruption, abuses of labour laws and human rights including child labour, fatalities or injuries of workers[50]. Last but not least, the long-distance shipping of the essential materials and inputs will, of course, also significantly impact electric vehicles' overall carbon footprint.

In addition to supply chain vulnerability, the biased distribution of natural recourses and excess demand are likely to result in a significant upward price trend subject to substantial swings. At least in the short to medium term — until the industry devises ways to reduce the use of essential raw materials in car production or increase supply (such as better recycling, new technologies and/or new mines[51]) — rising demand will push prices up. As Chart 68 shows, metals that are essential in the production of (batteries for) electric vehicles such as cobalt, lithium and nickel have followed a (sometimes steep) upward trend since about mid-2020. The mining industry's leading forecaster Benchmark Intelligence warns that the mounting cost of key raw materials is likely to play a role in battery costs, thus possibly jeopardising the widely projected decline in battery prices (see Chapter 1.4) and therefore carmakers' electric vehicle sales plans in 2022-2024 (Jennings-Gray et al., 2021). The price development of magnesium has a slightly different history that does, however, exemplify previous statements. Magnesium is not specifically used in electric vehicle production, but about 40% of worldwide output ends up in car parts in general. China produces about 87% of the world's magnesium; nearly half of China's production heads to Europe which, for its part, covers 95% of its magnesium needs with imports from China. Furthermore, the production of magnesium is highly energy-intense, as some 4 kg of coal has to be burnt to produce 1 kg of magnesium. To comply with emission targets, Chinese authorities ordered some producers to either shut down or reduce their

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Europe, such as underneath the Rhine valley in Germany and the Lozinca area in Serbia. Yet these deposits too will be subject to the same challenge of overconing political hurdles and extracting the ore economically, combined with the missing processing infrastructure for transforming the lithium-containing minerals into LiCO, LiOH and/or then Li-salts.

[48] The New York Times reports 15 out of 19 in 2020. A Power Struggle Over Cobalt Rattles the Clean Energy Revolution - The New York Times (nytimes.com).

[49] Despite the political will to strive for raw material independence, the European Union/Europe's capacity to substitute for imports of raw materials from EU/European resources seems limited, at least in the medium term. Looking at the recent mining permit history across the European Union, it does not seem very probable that a large share of the raw materials for batteries will come from the EU or even European primary resources. While there are some projects in their early stages (some highly controversial, such as the lithium deposits in Serbia), if some of these projects materialise the share of primary raw materials from the European Union/Europe is likely to remain small. It has to be borne in mind that between raw material extraction and cell manufacturing, there are complete supply chains involving several processing steps. Most of those are missing in the European Union, or capacity only covers a small part of future expected demand. Moreover, processing or refining steps are to a certain extent considered more critical than the raw material extraction steps.

[50] See, for example, IEA (2021b) or Castelvecchi (2021) for more details.

[51] …which do not really seem to be on the immediate horizon yet. See Castelvecchi (2021).

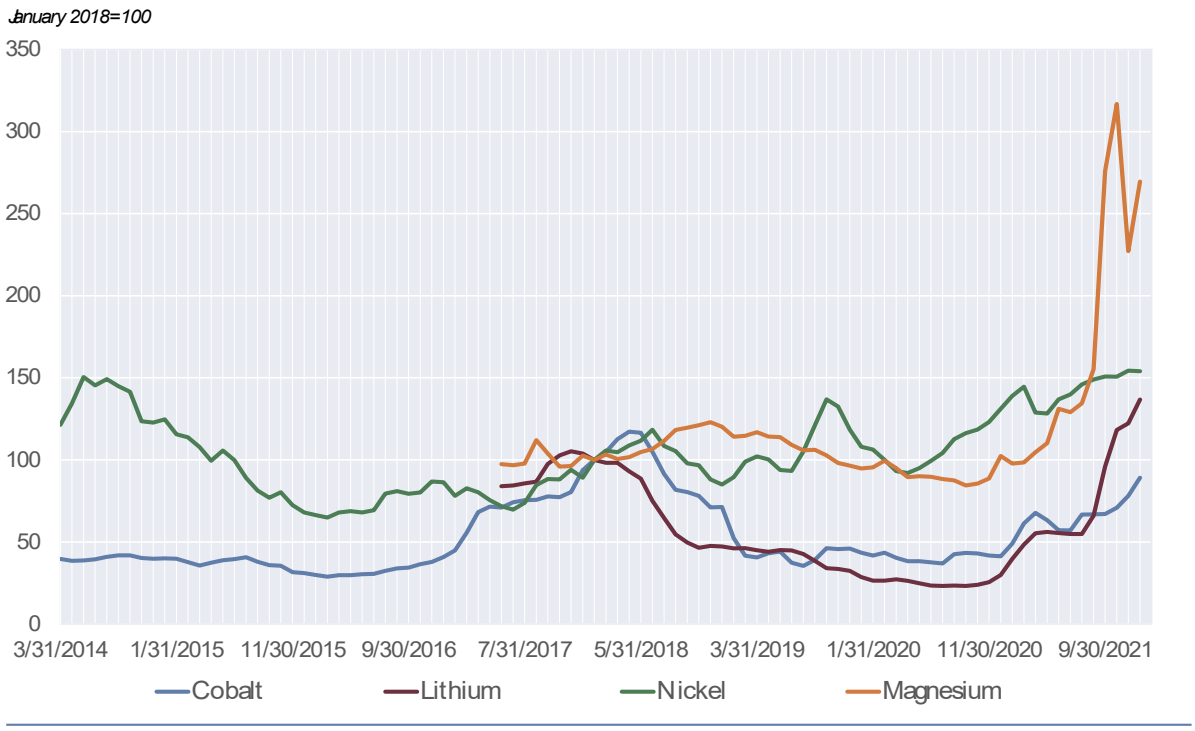
output. This brought about an unprecedented spike in the price of magnesium in October 2021 and the subsequent volatility reflecting the somewhat increased yet still throttled production. The price hike and swings sparked serious concerns from the likes of the German metals trade association, WV Metalle, that the country could exhaust its magnesium reserves[52]. Since diversification options outside of China are limited, this case demonstrates both the critical dependency on Chinese supplies and how their local (environmental) policies may exacerbate the asymmetric reliance. The rollercoaster price development of cobalt between early 2016 and mid-2019 also provides a telling insight. In the two years to the first quarter of 2018, the price of cobalt had nearly quadrupled, but collapsed precipitously almost back to its 2016 levels in the following 15 months, losing 70% from its peak value. One of the key factors in this development was the fact that projected electric vehicle sales triggered a cobalt rush, but then actual growth rates for the sector failed to live up to expectations[53]. This case therefore suggests that not only is actual excess demand likely to drive up prices of key components, but market expectations may also lead to high price volatility.

While the automotive industry in CESEE will face the same supply chain bottlenecks, the region may play some role in the diversification of the exposure risks, subject to social and environmental challenges. In addition to some of the world's most significant lithium deposits having been discovered beneath the Rhine River in Germany, there are also about 4% of worldwide reserves in the North-Western corner of the Czech Republic waiting to be unearthed. Yet lithium mining carries its own environmental concerns: barring lasting ecological damage to the landscape, current forms of extraction require plentiful amounts of energy and/or water (Castelvecchi, 2021). For that reason, authorities in Serbia have been forced by massive protests to suspend plans that would allow the highly disputed mining company Rio Tinto to operate a lithium mine in Western Serbia where there are reportedly some of the world's most significant lithium deposits. The excavation — according to the company "the largest mining investment in this part of the world" — was supposed to start soon. The project has been put on hold and according to the Serbian government its implementation will hinge on public acceptance and an environmental impact assessment.

[52] WirtschaftsVereinigung Metalle - Artikel: Internationaler Lieferengpass bei Magnesium aus China: europaweiter Produktionsstopp droht (wvmetalle.de)
[53] Why Have Cobalt Prices Crashed (internationalbanker.com)

Chart 68

Price development of selected metals essential for electric vehicle production



Source: www.investing.com.

4.2.3 Carbon footprint

While electric vehicles are seen as a means to achieve a carbon-neutral future, the evidence on their carbon footprint is mixed. Together with the other environmental issues mentioned above, the life cycle carbon emission balance of electric vehicles is also not clear-cut, despite their zero CO_2 tailpipe emissions. Car, country and energy source-specific factors clearly determine the performance of different vehicle types. A brief sample from a wide range of literature that we can provide here should therefore help to outline the carbon dichotomies related to electric vehicles. In a nutshell, among the most prominent factors contributing to electric vehicles' CO_2 impact are: i) the energy mix used for producing cars and for charging them; ii) the energy demand and greenhouse gas emissions of battery production; and iii) the average daily vehicle distances travelled.

Clean energy is a necessary prerequisite for enabling electric vehicles to outperform alternative powertrains in terms of carbon emissions. Cox et al. (2020) conduct a study on the life cycle environmental burden and total cost of ownership for the current and 2040 generations of cars under different electricity scenarios. Their overall conclusion is that electrification of passenger vehicles is effective in reducing greenhouse gas emissions, although the degree of optimal electrification to minimise them is strongly dependent on the electricity mix used for charging. Countries with mostly green energy supply would benefit from larger battery electric penetration in the private vehicle market in terms of lower greenhouse gas emissions. Wherever clean energy is not available, plug-in hybrids and hybrids are the best choice in terms of cost and climate benefits. Support for the conclusions of Cox et al. (2020) also comes from Inaba et al. (2019), who select the United States,

European Union, Japan, China and Australia as reference regions for the use of battery electric and internal combustion engine vehicles and their emittance of greenhouse gases. Again, they find that under the current energy mix, battery production is the reason why CO_2 emissions from battery electrics are greater than those of internal combustion engine vehicles[54]. However, if the energy supply is largely renewable and/or battery production is improved, the emissions performance of battery electrics tops that of internal combustion engine vehicles, although the results are subject to other factors such as the assumed mileage and whether/when a battery replacement is necessary. The problematic sustainability aspect of battery production is emphasised by Yang et al. (2020), who find that greenhouse the gas emissions of electric vehicles in China are significantly higher than those of fuel cell electric and internal combustion engine vehicles, mostly due to the high energy consumption and emissions of battery production[55]. Over higher driving mileage, fuel cell electrics perform best in all scenarios. Ahmadi et al. (2018) analyse minimum emissions among alternative powertrains in the United States, depending on varying average daily vehicle miles travelled. They find that plug-in hybrids win out. All other things being equal, the success of reducing emissions via a focus on battery electrics will therefore crucially depend on the future energy mix, the progress in developing cleaner batteries, the battery electrics' average mileage or possible changes in individual mobility behaviour.

4.2.4 Future of individual mobility, new entrants and eroding comparative advantages of traditional automotive firms and countries

"Cars will continue to be in demand and produced on a significant scale in the future — in Europe too. Yet the key question is by whom." This is how Martin Jahn, board member of Skoda Auto, replied at the EIB-OeNB Conference on European Economic Integration in November 2021 when he was asked about the future of individual mobility and a possible shift towards public transport. The long-lasting car manufacturing tradition has for decades given the European automotive sector a significant comparative advantage. However, car electrification is a technological game changer. The automobile market is a dynamic one. While former giants like General Motors and Ford were the largest manufacturers of vehicles globally in 2000 (OICA, 2021a), Toyota and Volkswagen took over the lead positions in the following years (OICA, 2021b). With a market capitalisation of over USD 1 trillion, the relatively new car producer Tesla dwarfs its competitors in market capitalisation, which reflects the market's expectations about future sales. Other new players like the US producers Rivian and Lucid Motors challenge the established car producers in market capitalisation, albeit not in production numbers so far.

There is also an increasing number of Chinese companies that are — with strong support from the Chinese government — eyeing massive expansion to Europe in terms of sales, production and R&D. After several failed attempts to enter the European market in the past, the starting position of some Chinese companies is considerably more promising this time. They have made a quantum leap from technological laggards to innovation and technology trend-setters in many instances. To catch up and get a foot in the European door, Chinese firms have not only accumulated brilliant know-how — including by draining excellent (European) management, designer and engineering brains — but have also acquired control over renowned European automotive firms such as the British MG and Swedish Volvo. Furthermore, the Chinese company Geely is also the biggest shareholder in Daimler with nearly

[54] CO_2 emissions of transport of batteries and/or raw materials do not seem to be fully taken into account.

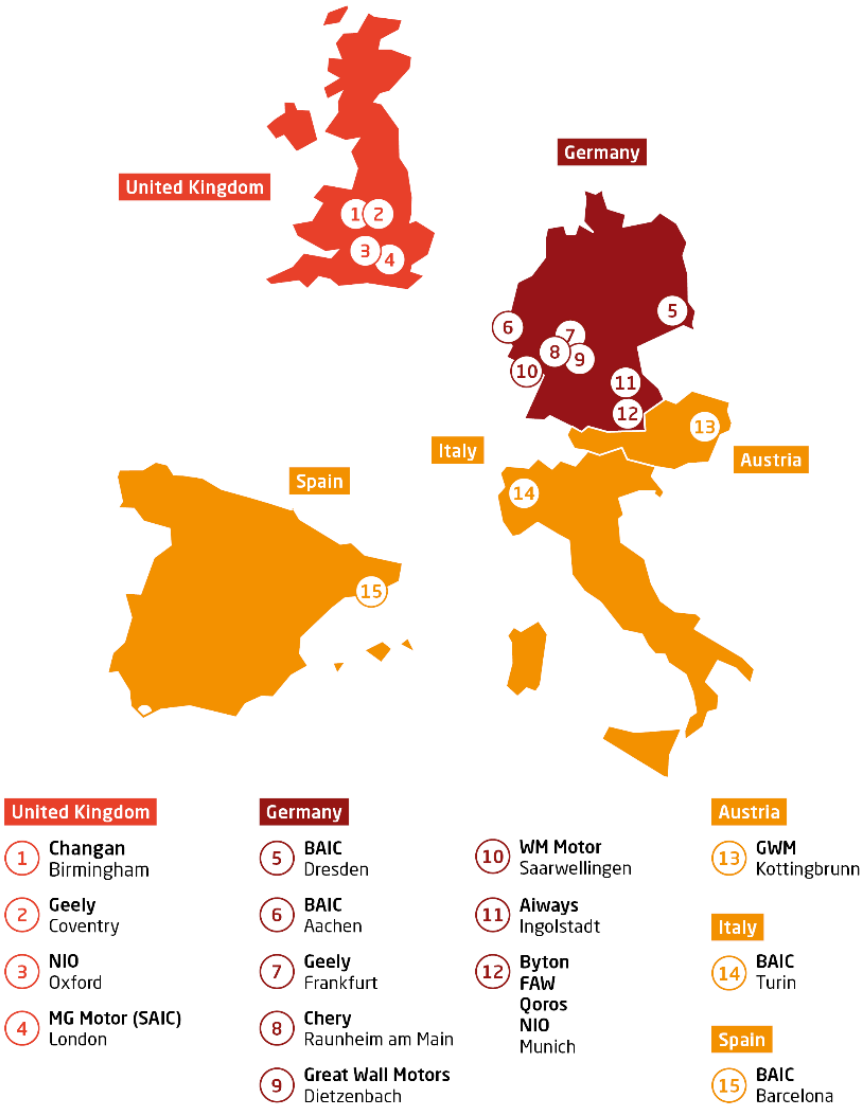
[55] In the vehicle life cycle, energy consumption and greenhouse gas emissions of an electric vehicle in China are 1.4 times that of an internal combustion engine vehicle and 1.2 times that of a fuel cell electric vehicle, which directly offsets the advantage of the electric vehicle with respect to the fuel life cycle.

10% of shares. In addition, Chinese car manufacturers have been establishing R&D and design centres in (Western) Europe, which help them comply with European regulations and tailor design and software solutions to European customers (see Chart 69). To avoid tariffs and rising shipping costs, it is the next logical step to place the production of parts (particularly batteries), as well as the assembly of cars, in Europe.[56] As a result, taking advantage of i) the technological lead of Chinese firms in the realm of new mobility; ii) the support of the Chinese government; iii) a crucial position in global supply chains; and iv) strategic control over most essential raw materials, a large-scale expansion of Chinese firms such as BYD, Great Wall Motors, NIO or XPeng to Europe will likely pose a significant challenge for traditional European automotive companies, including for their locations in CESEE.

[56] For a detailed analysis of the Chinese expansion to Europe see, for example, Sebastian (2021).

Chart 69

Chinese R&D and design centres established in Europe since 2015



Source: Sebastian (2021).

The loss of dominance is not limited to established automotive companies, as the country-level dynamics also evolve. Until 2005, the United States was ahead in terms of cars produced per country, before it was overtaken by Japan, which in turn lost its lead in 2009 to China (OICA, 2021c). Regarding Europe, Pavlínek (2021a) analyses the core-semiperiphery-periphery spatial structure of the European automotive industry during the 2003–2017 period. He shows that the stable core was dominated by Germany and also includes France and Italy. The stable semiperiphery is located in Western Europe with unstable borderline cases Sweden and Great Britain, which have trended down from the core to the semiperiphery. The periphery is predominantly located in the CESEE region and its most distinguishable features include a very high degree of foreign control and weak innovation capabilities, despite a large automotive industry in several of the peripheral countries. Pavlínek (2021a) argues, in

line with Mordue and Sweeney (2020), that for the peripheral countries to advance into the semiperiphery of automotive transnational production networks, a large modern automotive industry may not be sufficient, unless they have a reasonably strong domestic sector, including firms that are able to globalise, and have sizeable innovation activities.

The outlook for the CESEE countries is mixed. The previously robust growth of (foreign direct investment flows and relocation into) the automotive industry in the region slowed down after 2009 (see Chapter 2.3). According to Pavlínek (2021a), the rapid growth experienced in the past is unlikely to be seen in the future because of the increasingly exhausted labour pool and thus rising wages. Consequently, he concludes that due to the predominantly foreign ownership and control of the automotive industry in CESEE, the only way to improve the relative position is via strengthening of innovation activities and shifting to higher value added production, which indeed has been happening to some extent over the last decade. Similarly, Carreto Sanginés et al. (2020) argue that much more selective functional upgrading is crucial for maintaining the competitiveness of the CESEE automotive industry. Yet as detailed in the previous chapters, owing to the limited innovation capacity — despite some exceptions and recent improvements — and the functional specialisation trap (see Box 2), it seems rather unlikely that the car industry in the region will catch up in terms of innovation capacity with Western European countries and move up the value added ladder significantly any time soon. On the one hand, digitalisation and automation may provide an opportunity for CESEE countries to attract and accrue technological and R&D activities that have been traditionally sited in headquarters locations (Carreto Sanginés 2020). On the other hand, however, Drahokoupil (2020) argues that industry 4.0 undermines the key comparative advantage of peripheral producers (lower labour costs and labour flexibility). Automation thus questions the very rationale for relocating labour-intensive business processes to low-cost countries. Overall, it is difficult to assess how all these factors will play out in the European car industry in general and in CESEE in particular. We agree with Pavlínek (2021a) that the transformation of the industry to new trends in CESEE is likely to lag behind Western (core and semiperiphery) countries and the region will stick to internal combustion engine technology for longer (possibly to serve non-EU markets and/or continued local demand for internal combustion engine vehicles). In the short to medium term, this is likely to imply lower investments but possibly also some diversification of the transformation risk. For the CESEE automotive industry to stay competitive in the medium to long term, it will be crucial to stay on top of battery production and attract foreign direct investment activities with higher value added, including from beyond the car industry (in the IT and chemical sectors). While the region's labour cost advantage is likely to fade over time, this will happen in parallel with the diminishing importance of labour costs in production.

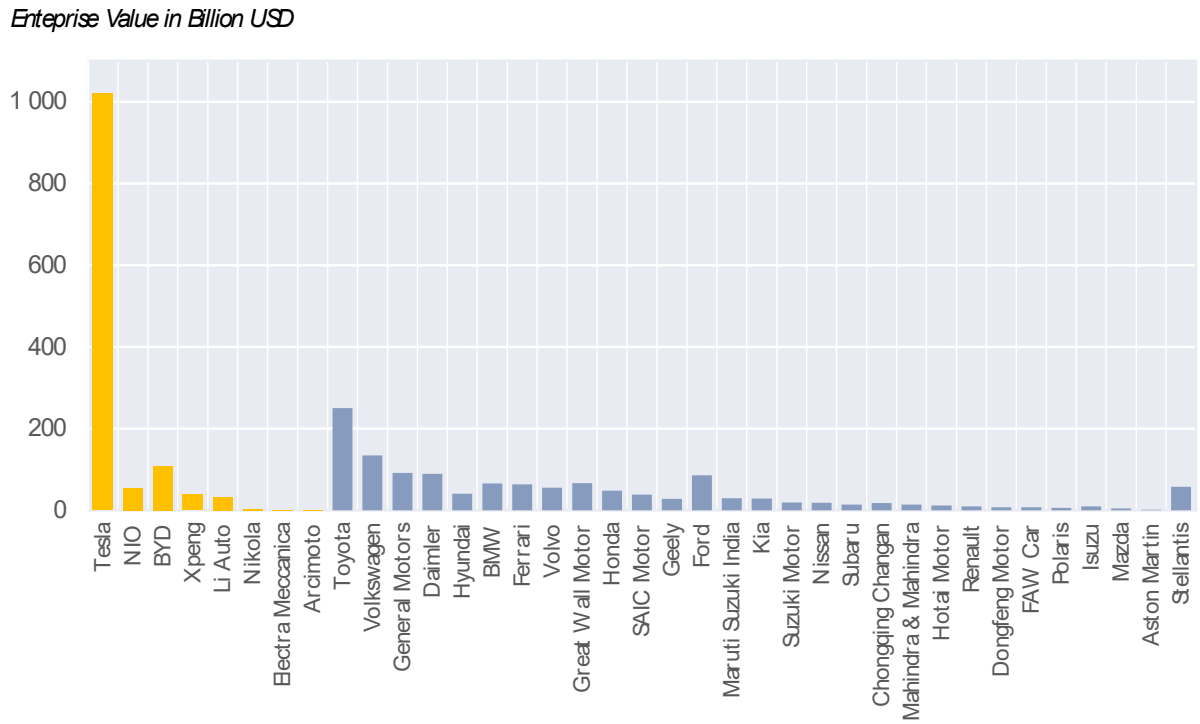
4.2.5 Financial sector risks

The electric vehicle sector is seeing vast capital inflows, to the extent that the market capitalisation of electric vehicle specialists matches that of traditional automakers. The two segments of the automobile sector have similar values of about USD 1.3 trillion in market capitalisation (see Chart 70). While the leading electric vehicle producer by enterprise value, Tesla, is a clear outlier, other specialists also exceed well established competitors in the traditional automaker industry. Arnott et al. (2021) call this parallel rise of direct competitors in an evolving industry the "big market delusion".

Chart 70

Enterprise value of electric vehicle specialists vs. traditional car manufacturers

(as of 14 December 2021)



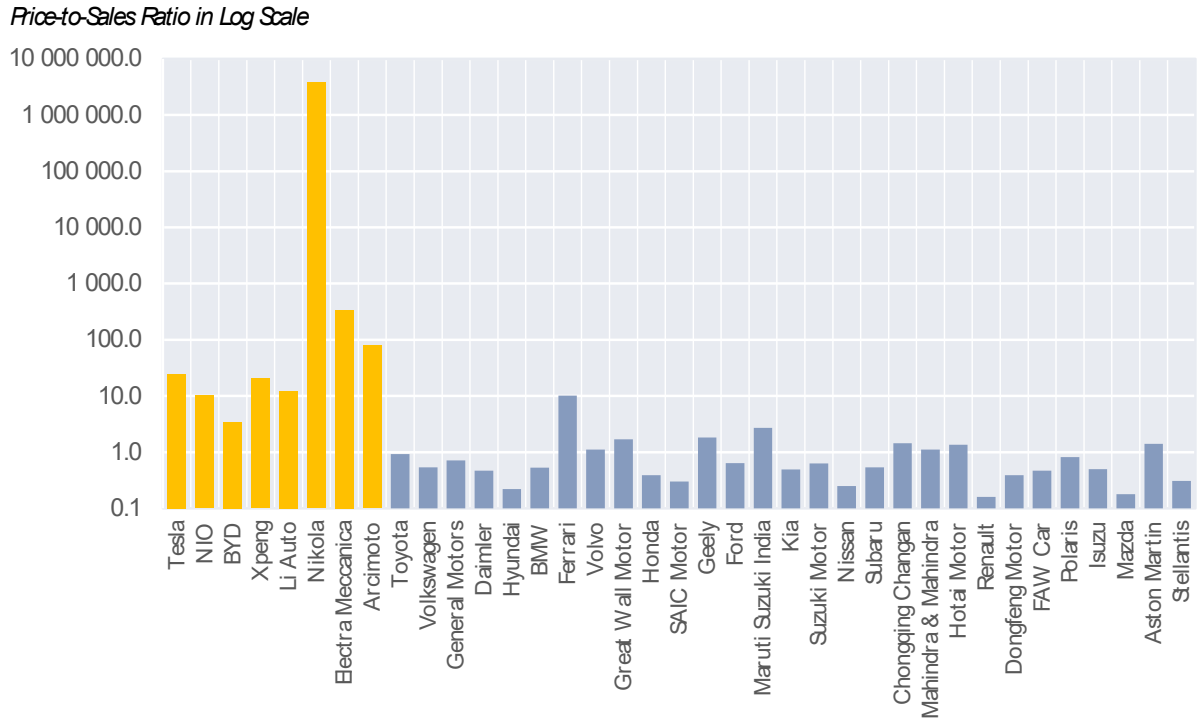
Source: Yahoo Finance.

Relating market valuations of electric vehicle manufacturers to their performance suggests unprecedentedly exuberant expectations, as shown in the price-to-sales ratio of these companies (see Chart 71). Even without the extreme outlier Nikola, which exhibits a price-to-sales ratio of about 4 million (due to very limited sales so far), the combined price-to-sales ratio of electric vehicle specialists exceeds that of traditional automakers by a multiple. Applying an enterprise value weighted price-to-sales ratio, the electric vehicle specialists trade at a multiple of 21.8 (without Nikola), while the traditional automakers reach a value of 1.2. Considering an equal weighted approach, the difference becomes even larger. In that case, the electric vehicle specialists show a price-to-sales ratio of 70.2 while the traditional part of the sector trades at a multiple of a mere 1.1. For the sake of comparison, NASDAQ-listed sectors yielded an (equally weighted) average price-to-sales ratio of 11.4 just before the dotcom bubble burst in March 2000 (Horstmeyer and Vij, 2020). These figures show the immense magnitude of expectations that are currently priced in for the electric vehicle sector. Arnott et al. (2021) point out that over the last three years, electric vehicle specialists' combined total revenues averaged less than 2.5% of those attained by the traditional carmakers. In addition, Tesla's market capitalisation suggests that the market expects the company to come to dominate the entire industry, not just the electric vehicle segment in an unseen way. The company would have to achieve profit margins higher than those of Ferrari while exceeding the production volumes of Toyota. Such high expectations raise concerns about what happens if they are not borne out in reality. If this implied revaluation risk were to materialise in a form of a rapid fall in valuations and fire sales, it might entail further knock-on effects on financial institutions and other investors with financial stakes in electric vehicle companies.

Chart 71

Price-to-sales comparison, electric vehicle specialists vs. traditional car manufacturers

(as of 14 December 2021)



Source: Yahoo Finance .

Concerns about the sustainability and rationality of expectations regarding the future performance of electric vehicle manufacturers is not confined to equity, but also extends to debt financing. As political and public attention paid to the environmental, social and governance agenda intensifies, climate-related banking regulations are also being developed. Banks, including those in CESEE, are being incentivised to change their business models and rebalance their asset portfolio towards less carbon-intensive credit exposure, in line with the EU taxonomy[57]. This includes funding provision for electric vehicle manufacturers, as the EU taxonomy sees these vehicles as fully compliant with the path to carbon neutrality targets[58]. The climate-related risk and financial stability regulations and supervision are based on the key assumption that the transition risk (from brown to green assets) of borrowers, and thus also the exposure of banks to these risks, rises with the carbon emissions intensity of the borrower (ECB, 2021). The transition to a low-carbon economy is therefore affecting industries that emit a large amount of CO_2 more than industries that emit relatively little. Overall, the transition risk quantification seems mainly defined as (CO_2-intense) "brown assets" losing value or higher costs of doing business for "brown" companies, which imply an overvaluation of these assets and consequently firms (Bank of England, 2021; Vermeulen et al., 2019). Specifically, market and credit

[57] See Raiffeisen (2021) for examples and more details.

[58] Transport by motorbikes, passenger cars and light commercial vehicles - EU Taxonomy Compass | European Commission (europa.eu)

risks resulting from the uncertain business models of green companies and their assets and the emergence of disequilibria and mispricing of green assets certainly deserve attention.

4.2.6 Labour market implications and risks

The future employment changes in the automobile sector will be massive, affecting almost all jobs in the industry (Galgóczi, 2019). Electric vehicles are less labour-intensive than their internal combustion engine counterparts owing to significantly lower complexity and a higher degree of automation in production and assembly (an internal combustion engine is composed of some 1 200 parts, an electric engine only of about 200). As a result, it is highly likely that the transition to electromobility will have a noticeable impact on employment in the automotive sector, and this is a source of particular concern for CESEE countries where the automotive sector is among the most significant sources of employment. However, estimating how many jobs will get lost, emerge or shift to other sectors is a complex issue as vehicle electrification coincides with several other factors that would have an impact on employment in the industry. While certain jobs related to the production of internal combustion engine vehicles will become obsolete, new jobs will emerge in the car industry and beyond. There is a continuum of possible impacts of vehicle electrification on individual automotive companies, but there is also a large number of options for how each and every one of these companies could react to these (anticipated) impacts. This holds true in particular for upstream suppliers of components directly related to the internal combustion engine such as fuel injection systems and gearboxes. According to surveys and anecdotal evidence, firms' reaction strategies vary from a rather relaxed wait-and-see approach to proactive diversification and re-orientation to other segments or products. However, the shift to electric vehicles will not only affect companies currently specialising in internal combustion engine-related products, but also firms whose output is seemingly unrelated to powertrain technology, such as tyres. According to representatives of Goodyear interviewed for this research project, tyres for electric vehicles are more complex than for internal combustion engine vehicles. Firstly, they are subject to higher pressure, as electric vehicles are heavier. Secondly, particular attention has to be paid to tyre noise, as electric vehicles are quieter. Lastly, electric vehicle tyres must have different features owing to faster acceleration. The shift to electric therefore requires new product and innovation investments, and might also have implications for employment.

Future employment changes in the automobile sector are not straightforward and are hard to predict (Galgóczi, 2019), even in the particularly well researched German market. As Germany is one of the world's major automotive hubs — where the industry directly employs more than 800 000 people[59] — this question has been relatively widely examined in analytical studies. While earlier research papers are rather inconclusive on the macroeconomic impact of powertrain electrification[60], more recent studies (often updates of previous versions) project increasingly significant negative impact on employment. In a recent seminal paper, the Institute for Employment Research (an institution of the Federal Employment Agency) takes a top-down approach to modelling future global industry developments resulting from vehicle electrification (Mönnig et al., 2019). The authors project that a net increase in employment will take place in the initial few years of technological change due to transition and investment needs. Yet this positive impact will be vastly overcompensated in the subsequent years. As a result, the change in powertrain technology is projected to cause around 130 000 gross job cuts in Germany by 2035, 83 000 of which will be in the automotive industry alone.

[59] This is comparable to the aggregated employment in the six CESEE countries with the most significant automotive industry (Czech Republic, Hungary, Poland, Romania, Slovakia and Slovenia).
[60] See Keil (2021) for a detailed, though not conclusive, literature overview for Germany and Austria.

This negative impact on jobs will be mitigated by the around 16 000 new jobs forecast to emerge. Skilled workers, experts and specialists will take the biggest negative hit, although only with a time lag. In addition to the negative impact on employment, the authors also project that the economy will lose nearly EUR 20 billion (0.6% of GDP) by 2030. However, in their scenario the authors assume a rather moderate share of 23% for electric vehicles until 2035. The various effects on GDP and employment in both positive and negative directions would be stronger with higher electric vehicle market penetration. Using a different approach, another recent influential estimate is offered by ELAB 2.0 (Bauer et al., 2018), a research project of the Fraunhofer Institute for Industrial Engineering IAO in partnership with major German automakers and automotive suppliers. They use a bottom-up method, extrapolating the impact of car electrification on internal combustion engine-related components and processes. Depending on i) whether productivity increases are taken into account and ii) the scenario for electric vehicle penetration (ranging between 25% and 80%), the study concludes that the absolute number of job losses in the production of powertrains in Germany will range from 23 000 to 125 000 in 2030, out of slightly more than 200 000 in 2017. Building on and enlarging these two studies, the National Platform Future of Mobility (a multidisciplinary research joint venture funded by the German government) estimated that in a worst case scenario, more than 400 000 jobs in the German car industry could disappear by 2030 (NPM, 2020). However, it should be noted that this high estimate was severely criticised by the industry for being based on a highly unrealistic scenario.

There are few available estimates for the net job balance of powertrain electrification in Europe, and those that do exist are also inconclusive. To the best of our knowledge, not many studies have estimated the employment impact of the transition to electric vehicles across the European Union, let alone the CESEE region. Referring to the findings of the above-mentioned ELAB 2.0, McKinsey (2019) puts forward the following (somewhat ad hoc) estimate: "With PHEVs and BEVs accounting for 40% of the powertrain mix in 2030, electrification could result — depending on the vertical integration of today's automotive OEMs and suppliers in e-mobility — in a net impact of 0.3 million fewer direct and indirect manufacturing jobs in Europe in 2030 compared to 2018." McKinsey adds that the employment effects of other big car industry trends such as autonomous and connected driving (positive) and automation (negative) will offset each other. Similarly, using a granular model of 26 industries and 31 job families[61], Boston Consulting Group (BCG) concludes that all ongoing automotive industry trends except electrification will largely offset each other and cause only a marginal positive effect on employment in Europe (Kolo et al., 2021). In contrast to McKinsey, however, BCG also concludes that the transition to electric vehicles itself will bring about a relatively moderate net loss of 50 000 jobs in the European automotive industry. The most recent and possibly most comprehensive estimate of the impact of the electric vehicle transition on the labour market was carried out by CLEPA (European Association of Automotive Suppliers) and the consultancy PwC (CLEPA/PwC, 2021). Based on CLEPA and other associations' data as well as on surveys and industry interviews, the employment impact is forecast as a consequence of the countries' estimated value added development and an individual elasticity factor for internal combustion engine and electric vehicle technologies. In a baseline scenario on par with the European Commission's Fit for 55 proposal, the authors conclude that the value added[62] of the entire European automotive powertrain industry will increase by 55% by 2040, partially due to the higher number of units sold and the replacement of internal combustion engine vehicles with battery electrics, but also thanks to a higher average value added per vehicle. In

[61] The job families cover jobs in areas ranging from automotive R&D to automotive-related HR and IT. The job families are aggregated in five categories: engineering, procurement, production & service operations, sales and other functions.

[62] The study uses the term value-add which is defined as revenue minus material costs and describes the part of the company's individual value creation that directly contributes to the country's economy. In the present study we use the term value added.

contrast, the value added of mechatronic components will decrease by roughly 70%. Working on the key assumption that there will be a full battery value chain based in Europe (from the processing of raw materials to final battery assembly), the authors estimate about 270 000 net job losses until 2040 in the European automotive industry (see Table 6).

Irrespective of the net job balance, there is an unchallenged consensus that big trends in the car product market will entail massive structural transitions in the labour market between industries, job profiles and regions. It goes without saying that this will generate winners, losers and large transition costs. Today's automotive industry jobs — predominantly in direct and indirect manufacturing of cars and car parts — will shift to a significant extent to battery production, electronics, software and chemical industry as well as energy infrastructure and energy production. As the BCG authors (Kolo et al., 2021) concede, their relatively small net job balance estimate obscures the massive changes that will happen behind that figure. They estimate that the reduction in internal combustion engine-related labour effort for major automakers and suppliers, among other industries, will result in a gross loss of 630 000 jobs. However, this will be largely compensated by demand for batteries, charging infrastructure and other parts and services that will promote the creation of 580 000 jobs. In addition, they project that the shift to electric vehicles will also create temporary employment demand of around 400 000 construction person-years through 2030, mainly to build new battery manufacturing plants and charging infrastructure (Kolo et al., 2021). In a similar vein, CLEPA/PwC (2021) project about 500 000 internal combustion engine-related jobs in Europe (about 84% of the current internal combustion engine workforce) will be at risk until 2040 under the currently envisaged electric vehicle adoption scenario. At the same time, around 230 000 new electric vehicle-related full-time positions should emerge, about 200 000 of which will be related to all value chain functions of battery production. About 30 000 full-time jobs are expected to emerge in the production of electric motors.

While the automotive industry will see CESEE as an attractive location for producing electric vehicles, impact on employment is likely to be mitigated or delayed because the region is expected to remain reliant on the production of internal combustion engine vehicles and parts for some time. Based on his previous research, Pavlínek (2021b) states that production of internal combustion engine cars will continue for longer and mass production of electric vehicles will be slower in CESEE than in Western Europe. This is mainly due to the fact that older technologies tend to prevail for longer in peripheral locations, the CESEE automotive industry's relatively week innovation capacities and its continued (labour) cost advantage in the more labour-intensive internal combustion engine production. At the same time, CESEE will be an attractive location for potential new (for example, Chinese) electric vehicle assembly plants and the production of battery cells and components. These expectations closely match those of CLEPA/PwC (2021) covering automotive suppliers. Due to low labour costs and partially due to comparatively lower energy costs, the authors predict an increasing concentration of internal combustion engine vehicle powertrain production in selected CESEE countries, particularly the Czech Republic and Poland, in order to guarantee scaled production effects. Nonetheless, due to the electrification trend, approximately 50% of the remaining total internal combustion engine vehicle value added is expected to migrate to other regions outside Europe. In contrast, Germany, Spain and France are projected to ramp up electric vehicle production faster than other European countries, while Italy's low degree of innovation and automation together with high variable costs mean that it will see slow implementation of electric vehicle production. The authors state that France's beneficial nuclear and renewable energy mix means that it will be among the few countries to maintain its current powertrain employment with a strong increase in electric vehicle production. As a result of the concentrated internal combustion engine production and lower investments in the automation of the

outgoing technology, the Czech Republic, Poland and Romania are expected to increase their automotive employment levels until 2025-2030. While Romania's car industry is projected to suffer a major employment drop thereafter as a result of the shutdown of internal combustion engine production, Poland and the Czech Republic will experience a more gradual decline. Moreover, the Czech Republic in particular is expected to see a strong increase in electric vehicle-generated value added from 2030 on, to the extent that overall employment levels by 2040 could be broadly similar to those of today (see Table 6). While Hungary was not covered by the study, its internal combustion engine sector is also sizeable.

Table 6

Projected employment of full-time equivalents by the electric vehicle and internal combustion engine sectors

(in thousands)

		2020	2025	2030	2035	2040
Germany	ICE	132.7	134.3	105.3	10.5	10.5
	EV	17.9	34.6	39.6	50.4	57.3
	Total	**150.6**	**168.9**	**144.9**	**60.9**	**67.8**
Italy	ICE	72.9	73.8	6.6	6.6	6.6
	EV	1.1	3.7	5.0	7.4	8.2
	Total	**74.0**	**77.5**	**11.6**	**14.0**	**14.8**
France	ICE	24.0	24.3	2.1	2.1	2.1
	EV	3.8	12.0	15.7	27.0	29.4
	Total	**27.8**	**36.3**	**17.8**	**29.1**	**31.5**
Spain	ICE	70.0	70.9	99.0	6.5	6.5
	EV	2.0	18.9	28.1	37.4	39.4
	Total	**72.0**	**89.8**	**127.1**	**43.9**	**45.9**
Czech Republic	ICE	37.0	37.5	25.4	33.3	16.9
	EV	3.7	11.6	15.2	21.7	23.9
	Total	**40.7**	**49.1**	**40.6**	**55.0**	**40.8**
Poland	ICE	51.7	52.3	68.8	49.7	25.3
	EV	3.5	9.4	12.3	17.0	18.7
	Total	**55.2**	**61.7**	**81.1**	**66.7**	**44.0**
Romania	ICE	54.0	54.7	71.2	4.6	4.6
	EV	2.2	13.2	16.8	22.1	24.0
	Total	**56.2**	**67.9**	**88.0**	**26.7**	**28.6**
EU27	ICE	599.3	606.8	512.7	153.4	98.3
	EV	46.2	139.9	179.6	247.9	272.2
	Total	**645.5**	**746.7**	**692.3**	**401.3**	**370.5**

Source: CLEPA.

4.2.7 Fiscal risks and opportunities

Countries worldwide have introduced significant fiscal incentives to motivate the initial uptake of electric vehicles. Electric vehicle pioneer Norway implemented such measures as early as the start of the 1990s, while the United States did so in 2008 and China followed in 2014. In the meantime, many other countries including Canada, Australia, Japan and India have some sort of fiscal stimulus for electric vehicles in place (IEA, 2021). In Europe, nearly all countries provide monetary impetuses for electrically chargeable cars. These take either the form of direct subsidies (such as bonus payments) or premiums. This is the case in 17 EU Member States, the United Kingdom and some cantons in Switzerland, and they can reach up to EUR 9 000 in Germany, EUR 10 000 in Italy and EUR 12 000 in France. Ten EU countries and Norway do not provide direct purchase incentives but rather support the shift to electromobility using tax reductions or exemptions for electric vehicles. While in Norway this

makes up a significant share of the electric vehicle price (IEA, 2021) and — according to Norwegian government estimates — total more than NOK 19 billion per year[63] (about 1% of general government expenses), in some countries such as Poland or Bulgaria the tax rebates are rather moderate (ACEA, 2020). Lithuania was until recently the only country in the European Union not to provide any monetary enticements, introducing compensation for buyers of both old and new electric vehicles in April 2021. For the time being, the support programmes are mostly limited in time and/or volume. For instance, Estonia has in the past (the last time in 2020) allocated only predetermined budgets from which bonuses were paid until the budget had been exhausted. These policies are intended to act as motivational carrots for an infant technology, and as it stands they are expected to be phased out in line with the growing popularity of electric vehicles.

Irrespective of fiscal support for electric vehicles, their rising numbers are increasingly becoming a fiscal issue for both revenue and expenditure, and governments will need to put the situation on a sustainable footing. In addition to direct and indirect support for electromobility, rising electric vehicle sales will affect public budgets in other, even more fiscally significant ways. On the one hand is large expenditure on infrastructure investments, particularly for charging, energy production and transmission. On the other are the foregone revenues stemming in particular from value added tax (VAT) and excise taxes as a result of declining sales of internal combustion engine vehicles and their operation. According to ACEA (2021), motor vehicles generate a tax revenue totalling nearly EUR 400 billion in 13 key European markets (none in CESEE). The bulk of this amount comes from taxes on fuel and lubricants as well as from VAT on vehicle sales, servicing, repair and parts[64]. Belgium raises the highest average total tax revenues per vehicle (EUR 3 187) followed by Austria (EUR 2 678) and Finland (EUR 2 523). Cars thus contribute about 9.4% to the Belgian general government's overall revenues, while this figure is 8% in Austria, 7.9% in Finland and 6.4% in Germany. Some frontrunners in electromobility are therefore unsurprisingly already facing the fiscal consequences of a lack of fossil fuel-powered cars to tax. In Norway, more than a quarter of registered passenger cars are battery electrics, plug-in hybrids or hybrids. Furthermore, while about half of new cars sold in 2020 were electric, recently nearly 80% (September 2021) of all new cars sold were battery electrics. Policy makers are thus pondering ways to strip electric vehicles of their special treatment while not choking off the demand and endangering the country's goal of an internal combustion engine vehicle sales ban by 2025. An additional constraint is the national binding standard under which fees for electric vehicles should not exceed 50% of those charged for conventional cars. The Norwegian government is thus developing a new car tax system that should be economically sustainable after 2025. Another example is the Australian state of Victoria, where the local government has started to tax electric vehicle owners for every kilometre driven. In other words, public authorities will increasingly face the task of how to square the fiscal circle (or rather the challenging trinity) of i) boosting demand for electric vehicles (to live to up to electric vehicle sales and internal combustion engine vehicle ban targets); ii) investing in the enabling infrastructure; and iii) ever fewer internal combustion engine vehicles and lower fuel consumption to tax.

At the same time, governments are likely to be increasingly confronted with critical questions about doubtful value added for taxpayers' money and adverse distributional effects. Germany and particularly Norway are a case in point that may help inform policies in other countries. Heymann (2021) estimates that in Germany the total fiscal effect of replacing a combustion engine upper mid-range car with an equivalent battery electric model can total (in the form of direct subsidies and tax revenue losses) to more than EUR 20 000 over the car's lifetime. For every million electric cars sold in

[63] Norway is electric - regjeringen.no

[64] Electric vehicles are less service and repair-intense than internal combustion engine vehicles.

Germany in the next few years, the total fiscal effect is thus projected to amount to at least EUR 15 billion over the 12 years after the sale. Cloete (2021) calculates that, due to tax rebates, a typical upper mid-range battery electric car in Norway generates USD 23 300 less in tax revenues than a comparable plug-in hybrid and USD 36 500 less than an equivalent hybrid[65]. In other words, the sum of all taxes and fees that a consumer pays for a typical hybrid car in Norway would be enough to buy another car in other western markets (such as the United States). Cloete (2021) also calculates that the typical battery electric considered avoids about 15 tonnes of CO_2 relative to a hybrid[66] over its life cycle, under the assumption that electricity generation emits no CO_2 (as is the case in Norway where electricity is almost completely generated by hydro power). The CO_2 saving relative to a plug-in hybrid is about 6 tonnes. This means that combining the foregone tax revenues with the CO_2 avoidance implies that the fiscal cost per avoided tonne of CO_2 amounts to USD 2 400 in the case of a hybrid and USD 3 900 for a plug-in hybrid. This is in stark contrast to the current level of about USD 90 per tonne of CO_2 in the European Emission Trading System. Yet Cloete (2021) considers the argument in more detail. For Norwegian public finances to make up for the tax breaks granted to battery electric buyers, the country — a major oil and gas exporter — needs to sell 104 more barrels of oil than for a hybrid and 170 barrels more than for a plug-in hybrid to avoid 1 tonne of CO_2[67]. But these extra barrels of oil also generate additional CO_2. This translates into 45 tonnes (compared to a hybrid) and 73 tonnes (compared to a plug-in hybrid) more CO_2 generated through additional oil sales to avoid 1 tonne of CO_2 with a battery electric car. The lower the share of green energy in a country's energy mix, the higher these abatement costs will be — so the costs will of course be greater in countries with more CO_2-intense energy generation.

On top of the environmental effects at significant fiscal cost comes a highly problematic distributional aspect. Statistics Norway provides an interesting insight into the conjecture that it is the richest who benefit from the electric vehicle fiscal benefits, which are thus highly regressive. In 2019, electric vehicle sales were facilitated by about NOK 11 billion, while child benefit and the cash-for-care benefit together amounted to about NOK 17 billion. At the same time, 37% of new electric cars in that year were bought by the 10% richest households, while 50% of households with the lowest incomes purchased only 10% of new electric cars. In the top wealth decile, three out of four new cars were electric. As a result, in 2019 there were 21 times more electric cars per adult in the top decile than in the lowest decile (Fjørtoft and Pilskog, 2020). However, the fact that electric vehicles are bought mainly by the richest households has negative repercussions for their CO_2 savings. Using the extraordinarily rich Norwegian data, Camara et al. (2021) unsurprisingly show that emission savings are greatest if electric vehicles replace the most polluting internal combustion engine vehicles, rather than if they substitute for fuel-efficient cars or merely increase the overall number of cars. It is highly likely that the oldest and most polluting internal combustion engine vehicles tend to be concentrated in poor households, while rich households drive more modern and emission-efficient internal combustion engine cars. However, it turns out that most electric vehicles do not even replace old internal combustion engine equivalents. Camara et al. (2021) show that almost two-thirds of electric vehicle owners in Norway have at least one conventional car and that electric vehicles are used about 20% less in terms of median annual mileage than internal combustion engine cars. In summary, these findings suggest that it is mostly the richest households that buy publicly sponsored electric vehicles

[65] In 2019, electric vehicle buyers received about NOK 11 billion in advantages. Given that 46 000 new electric cars were sold, each one was granted tax and other fee breaks worth some EUR 24 000 on average. (see The wealthiest bought 4 out of 10 EVs - SSB)

[66] The comparison includes the entire vehicle cycle (including the production of components, fluids and batteries, assembly, disposal and recycling) as well as the well-to-tank fuel cycle and the tank-to-wheel fuel cycle.

[67] Under the assumption of a resource rent of USD 23 per barrel of oil for the Norwegian government.

as a second or third car to use them for shorter distances (probably particularly in cities where the advantages of electric vehicles can be enjoyed best). The environmental and distributional implications are therefore not straightforward.

4.3 Summary of macrofinancial impacts and policy implications for CESEE

4.3.1 Summary of expected impacts on macrofinancial developments in CESEE

While the CESEE region will continue to play an important role in the automotive industry and the European automotive supply chain, new opportunities may arise beyond that. Proximity to and close interlinkages with Germany — not only the current heart of European automotive industry but also very likely the future hub of European and global electromobility — are among the crucial determining factors. In addition, the already established presence of battery cell manufacturing capacity as well as the battery production capacity projects being implemented and/or planned are likely to help the region retain a role in a transformed automotive supply chain. Moreover, significant deposits of a few crucial raw materials in some CESEE countries may provide new opportunities for integration into value chains if ensuing environmental and social issues are resolved. The region therefore has the potential to be an integral part of the structural shift to electromobility, propelled not only by major automakers and automotive firms which are already well established locally, but also by potential newcomers, be it startups or firms from other geographical regions, particularly China. Moreover, technological developments provide new opportunities for firms well beyond the automotive industry, for example in the IT and chemical sectors.

Nonetheless, the adoption of new technologies and thus the transition of the industry is likely to trail behind that in Western European countries, bringing both advantages and disadvantages. Due to comparatively lower innovation capacity, the functional specialisation trap and a continued (although in light of the tight labour market, vanishing) labour cost advantage, the industry's shift to electromobility is likely to happen at a slower pace than in advanced Western European countries. The corollary here is that internal combustion engine production in the region will continue for longer, and will increasingly serve global markets where vehicle electrification will take place only in the much more distant future, if at all. On the one hand, the CESEE countries might thus fall further behind the cutting edge in terms of technology adoption. On the other hand, the continued production of internal combustion engine vehicles provides a diversification opportunity[68] and will also mitigate the impact of electrification, automation and digitalisation in the automotive industry on employment, at least in the medium term.

The impact of mobility electrification on the future structure and performance of CESEE economies seems ambiguous. While the shift to electrification and other trends in the car industry does require significant investment by major automakers and suppliers (not only with respect to cars, but also for battery production), investment in internal combustion engine technology will gradually wind down. In contrast, however, a large-scale shift of customers to electromobility in CESEE will require significant investment in the enabling infrastructure, particularly the charging network, but also in (green) energy

[68] It is not the internal combustion engine *per se* that causes the carbon footprint, but rather the fossil fuels that power it. Some automotive players foresee a promising future involving, for example, e-fuels whose production can be — with the use of renewable energy — largely carbon-neutral. While e-fuels can be used in existing internal combustion engine vehicles employing the existing fueling infrastructure, their production is currently rather uneconomical. E-fuels can also be used in the future for airplanes and trucks where batteries are not as easily deployed as for cars.

production and generation. If all of these investments were implemented according to the current climate target-driven plans and projections, it would provide a significant boost to investment and GDP growth. However, in addition to the enormous costs which need to be borne by public and/or private investors who will, at the same time, also face significant implementation and operation risks, these plans are subject to political and public opinion shifts as the costs of the transition become increasingly evident. Furthermore, investment might be impaired by tightening monetary and fiscal policy amidst a fragile post-pandemic recovery and accelerated inflation, at least in the short to medium term.

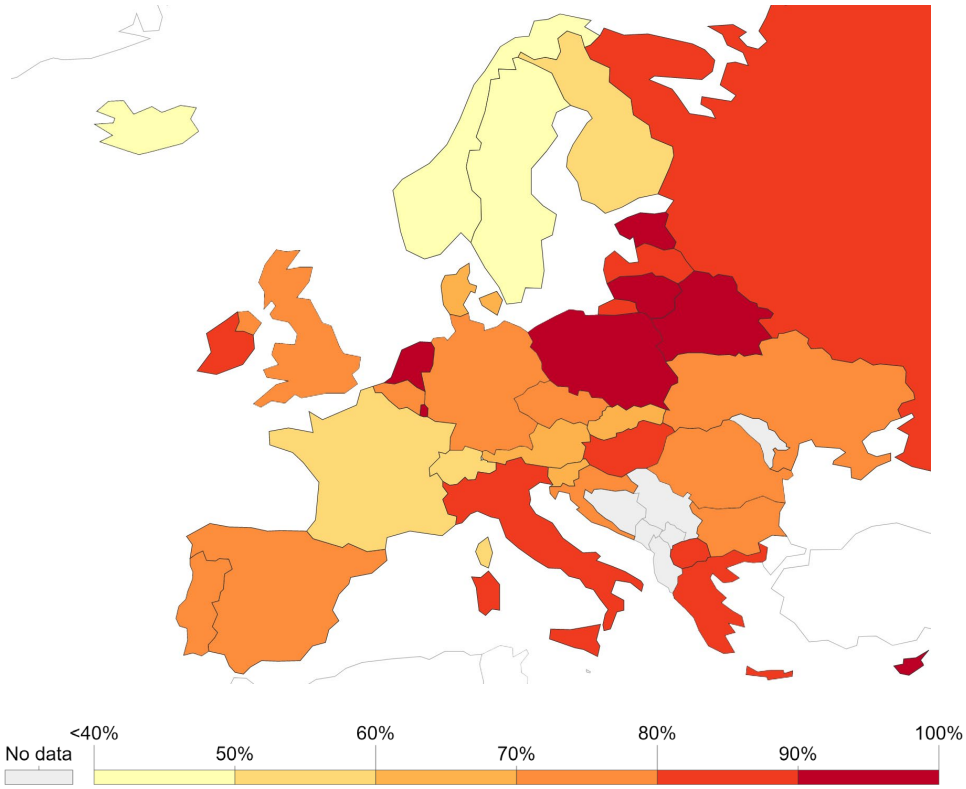
Fiscal and distributional effects of car electrification in CESEE countries notwithstanding, the overall reduction of the carbon footprint is also uncertain. The above-mentioned investments in infrastructure, energy production and transmission will, in the light of associated uncertainty, (have to) be covered to a large extent by public budgets. This comes in addition to fiscal support for the electric cars themselves, either in the form of subsidies or tax and levy rebates, which will seem increasingly unavoidable if electric vehicle sales are expected to take off to a significant degree, at least in the short to medium term. At the same time, revenues stemming from internal combustion engine vehicles and combustion fuels will decline. So far, the fiscal costs have been limited in CESEE countries. However, experience from other pioneering countries in the realm of electromobility suggests that some sort of fiscal support for electric vehicles is necessary to kick start sales. However, putting the fiscal consequences of mobility electrification on a sustainable footing without jeopardising demand turns out to be a rather complex exercise for fiscal authorities. Car prices are very likely to suffer from substantial upward pressure for some time due to a number of factors. Firstly, large investment and R&D costs accompanied by high uncertainty are likely to be reflected not only in the prices of new cars (both electric and internal combustion engine vehicles, with the latter used to cross-subsidise the former), but also in prices of electricity, some services (such as insurance[69]) and higher taxes. Secondly, rising demand for electric vehicles will drive up the cost of essential raw materials, the supply of which is limited and controlled by a small number of players. The supply-demand mismatch will therefore counteract the potential technology-driven fall in battery prices, meaning that past battery price reductions should be extrapolated with caution. In a similar vein, strongly rising demand for energy will be met by climate-policy driven targets concerning a rising share of renewables in the energy mix. As a consequence, rising energy prices seem inevitable, at least in the medium term. The demand for and prices of used internal combustion engine cars will also increase, as new (electric) cars will simply become unaffordable for many. Irrespective of the resulting distributional effects (which may lead to increased social and political tensions), the rising fiscal and inflationary costs may spark corrective reactions from monetary and fiscal policies. At the same time, holistic analyses of the CO_2 emissions of electric vehicles over their life cycle — even in countries with a high share of renewable energy like Norway —suggest that electrification is not likely to bring a significant carbon footprint improvement to CESEE countries until their energy mix (which currently features a rather high share of brown electricity production) shifts more towards renewables (see Chart 72).

[69] There are many other aspects that have not been discussed here in detail, but that may further increase prices. For instance, electric vehicle and charging stations are subject to potentially high costs in the event of fire. This will not only increase, for example, the insurance premiums for electric vehicles, but also safety requirements and thus costs in production or, for example, in parking lots. A whole set of other examples relate to potentially expensive repairs in electric vehicles, such as for the replacement of the battery, or for reasons as trivial as damage to the electrics caused by animals.

Chart 72

Share of primary energy from fossil fuels

(in % of total energy, 2019)



Source: Our World in Data.

4.3.2 Policy implications for CESEE

For CESEE countries to benefit from the electric vehicle revolution, the key priority is to maintain integration with the manufacturing core. It is particularly essential to preserve close links with Germany and stay on top of battery production, in cooperation with foreign strategic partners and investors. Governments may thus contemplate various instruments such as subsidies, tax incentives, different forms of support for jobs and/or infrastructure provision to attract (foreign direct) investment in new technologies, especially for the crucial area of battery production. In light of mobility electrification, electric vehicle and battery production, it will be of the utmost importance for CESEE economies to secure prospective affordable energy sources. Moreover, to reduce dependence on wage costs and boost efficiency of production, it is desirable for governments to provide conditions to spur digitalisation, automation and robotisation.

To overcome the functional specialisation trap of CESEE economies in general and of their automotive industry in particular, it is vital to attract foreign direct investment and activities with higher value added. The means to achieve this are manifold and include the provision of financing, subsidies, tax incentives and supportive conditions that incentivise cooperation between academia and industry. It also needs to be stressed that these measures should not be confined to the skills and qualifications immediately related to or relevant in the automotive industry today, but may well target

other sectors such as IT and the chemical industry, which will play an increasing role also in the car industry in the future.

While keeping the importance of the automobile industry and its new trends in mind, it is important for CESEE economies to diversify and address risks. As a result, while it is essential to attract new technologies in the automotive sector it is equally advisable to diversify the technological risks of the electrification trend by sticking in parallel to the production of internal combustion engine vehicles and serving emerging and developing markets into which electrification will find its way only with a time lag. At the same time, while acknowledging the important role of the automotive industry for CESEE economies, governments might also want to re-focus their attention on other promising sectors and industries of the future. The IT and chemical sectors, digitalisation and robotisation were mentioned in a slightly different context above, but apply here as well. In the Czech Republic and Romania, for instance, the digital economy contributes a similar share of GDP to the automotive industry. New opportunities may also emerge in areas such as (mechanical) engineering, in combination with green technologies. To support these new sources of future growth and economic convergence, governments should, again, mainly focus on the development of the required human capital. In addition, conditions need to be established so that the respective CESEE economies are attractive destinations for (both domestic and foreign) capital allocation, including venture capital. To facilitate these developments, countries in the region should also employ available EU funds, including those in the EU Recovery and Resilience Facility.

Last but not least, close monitoring of financial sector risks is warranted in light of the emerging imbalances in the electric vehicle sector. Table 7 below summarises our assessment of the future impact of new trends in the car industry on selected indicators in CESEE.

Table 7

Assessment of the impact of new trends in the car industry on selected indicators in CESEE economies

Indicator	Negative factors	Positive factors
Investment /(GDP growth)	– Phasing out of internal combustion engine technology, R&D – Implementation, operation, social and political risks	+ EV technologies + Investment and R&D in electric vehicle and battery production + Enabling infrastructure + Green energy production and transmission
Fiscal implications	– Significant public investment needs in infrastructure, energy production and transmission – Support for electric vehicles (subsidies, tax/levy rebates) – Declining fiscal revenues from internal combustion engine vehicles and fossil fuels	
CESEE Consumers	– More expensive new and used cars – Higher prices of electricity	+ Further reductions in battery prices (yet past trends have to be extrapolated with caution)

	– Higher prices of some services (such as insurance) – Phasing out of fiscal incentives	+ Possibly lower maintenance costs
Employment	– Much less labour intense electric vehicle production – Structural changes in the supply chains	+ New opportunities for existing and new suppliers and industries (particularly in battery and energy production) + Only a gradual phase-out of internal combustion engine vehicles + Opportunities in the new electric vehicle-related sectors
Financial sector implications	– Market overvaluation of and exuberant expectations of the electric vehicle sector – High uncertainty regarding large-scale market acceptance of electric vehicles – Regulatory incentives may lead to potential misallocation of resources and build-up of imbalances	– Regulatory and marketing incentives for banks and investors to prioritise financing of the electric vehicle sector provide continuity in the short to medium term
CO_2 balance	– High energy intensity of electric vehicle/battery production in combination with a high share of fossil-fuel generated electricity in CESEE – Mining and long-distance shipping of raw materials (particularly those used in battery production) – Underdeveloped/uneconomical recycling (of batteries) – Uncertain demand for second-hand electric vehicles – Electric vehicles so far typically bought by rich consumers as second/third cars, so electric vehicles do not yet replace the oldest and dirtiest cars on the roads – As cars will become more expensive, old internal combustion engine vehicles will be driven for longer, their average age will rise	+ Reduction of fossil-fuel consumption in the wake of the phase-out of internal combustion engine vehicles + Potential shift in mobility patterns (mainly in the most developed economies)

Source: Authors' compilation and assessment.

5 Conclusions

Numerous supply and demand side changes and trends, in particular the shift to electromobility, are increasingly shaping the automotive sector and will continue to do so. Since the sector plays a crucial role in several CESEE countries, the goal of this paper was to analyse to what extent the automotive industry in the region is prepared for these changes, and what implications, challenges and risks it will bring about.

120 years after its invention, the internal combustion engine seems to be an outgoing technology, with major carmakers phasing out investments into it and reducing the variety of vehicles using it. Their focus is increasingly shifting towards electric vehicles in growing varieties spurred on by ever-stricter regulations and peer and market pressure. The improving supply of electric vehicles in combination with fiscal incentives also stimulates demand, which has been accelerating fast (although from comparatively low levels).

CESEE economies have benefited significantly from the relocation of the traditional automotive industry from Western to emerging markets in recent decades. Yet within the automotive value chains, countries in the region tend to serve as factory economies, although less than in the past. Due to their labour cost advantage, they specialise in functions with comparatively lower value added and higher labour content compared to Western economies. Despite their comparatively low innovation capacity, the CESEE countries have gone through a large uptake of climate-friendly patents in the transport sector, providing an opportunity and a blueprint for a future move up the value added ladder.

The CESEE region is expected to be an important part of the European car industry's shift to electrification, and some countries — especially those with close ties with Germany — are even projected to become crucial hubs for electric vehicles and battery production. In addition to traditional automotive firms on whose foreign headquarters CESEE countries largely depend, new entrants can be expected to arrive on the automotive scene either from other geographical regions (particularly China) or as regional startups. At the same time, however, the shift to electromobility is likely to happen at a slower pace than in advanced Western European countries due to the above-mentioned comparatively lower innovation capacity, the functional specialisation trap and the continued though vanishing labour cost advantage.

In addition to chances and opportunities, the massive structural shift in the automotive sector will bring about significant challenges, costs and risks. On the one hand, there is major potential for CESEE countries to benefit from the transition to electromobility that could be sparked by large investments not only by traditional automotive companies already established in the region, but also by possible newcomers. As well as the conversion of production to electric vehicles, the newly emerging battery industry offers particularly attractive opportunities. These may thus extend well beyond the automotive industry to, for example, the IT and chemical sectors. On the other hand, reaping these benefits will be subject to challenges, costs and risks. These include rising prices (particularly for cars, energy and raw materials), as well as fiscal costs for the enabling infrastructure and electric vehicle incentives, together with potential overvaluations and exuberance on financial markets. Employment may be impacted too (electric vehicles are simpler than internal combustion engine vehicles and require less labour), although less than in Western European countries. At the same time, the impact on the carbon balance is likely to be limited until the current energy mix in CESEE shifts significantly towards renewables. With all of these factors in mind, the risk of political backlash and tensions cannot be discounted and it remains to be seen how it will all play out.

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