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The Future of the EU Automotive Sector

Abstract

This study provides an independent overview of the automotive industrial landscape in the EU. Specifically, the study assesses green and digital trends currently reshaping the automotive sector and provides recommendations considering the adequacy and consistency of ongoing and future EU actions.

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LIST OF ABBREVIATIONS

ADAS	Advanced Driver Assistance Systems
AI	Artificial Intelligence
AV	Autonomous vehicles
BEVs	Battery Electric vehicles
CAVs	Connected and autonomous vehicles
CAM	Center for Automotive Management
CCAM	Connected, Cooperative and Automated Mobility
CRM	Critical Raw Material
EC	European Commission
EMS	Electronic manufacturing services
EP	European Parliament
EU	European Union
EV	Electric vehicles
EFQM	European Foundation for Quality Management
FCH JU	Fuel Cells and Hydrogen Joint Undertaking
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GVC	Global Value Chain
HFCs	Hydrogen Fuel Cells
ICE	Internal combustion engine
ICT	Information and Communications Technology
IoT	Internet of Things
IT	Information Technology

JRC	Joint Research Centre
KPIs	Key Performance Indicators
LI-ION	Lithium-ion
MNCs	Multinational corporations
MS	Member States
OEM	Original Equipment Manufacturer
OS	Operating system
OTA	Over-the-air updates
PHEVs	Plug-in-hybrid electric cars
R&D	Research & Development
SAVs	Shared and autonomous vehicles
SMEs	Small and medium-sized enterprises
SDP	Supplier Development Programme
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TOC	Total Ownership Cost
UK	United Kingdom
US	United States
V1G	Smart Charging
V2B	Vehicle-to-Building
V2G	Vehicle-to-Grid
V2H	Vehicle-to-home
V2X	Vehicle-to-everything
VW	Volkswagen
ZLEF	Zero and Low Emission Vehicles

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EXECUTIVE SUMMARY

This study, conducted during Q3 2021 following the commissioning on behalf of the Committee on Industry, Research and Energy (ITRE) of the European Parliament (EP), provides guidance on optimising the balance between accelerating the environmental sustainability and digitalisation agenda and increasing the innovation-driven competitiveness of the EU automotive industry within the global value chain (GVC).

Challenges for the EU automotive sector

Accounting for over six percent of total EU employment and over seven percent of gross domestic product (GDP), the automotive industry faces the significant challenge of advancing the twin green and digital transition at a time when broader EU automotive interests are already threatened by increased global competition from both new entrants and existing companies from the Asia Pacific region, and North America.

While the COVID pandemic stress-tested the automotive GVC significantly, for example, in terms of the supply of semiconductors, it also acted as an accelerator positively impacting consumer demand for electric vehicles (EVs) along with electrification, digitalisation and GVC resilience measures. However, increased disruption, especially with new non-EU entrants, threatens EU jobs and the viability of many EU automotive enterprises. That the automotive industry will evolve more in the next decade than in the previous century means that there will be major winners and losers as a consequence of the following challenges, which include:

- Overdependence on world manufacturers outside the EU for EV battery propulsion 'red flags' the high risk of repeating the photovoltaic panel bubble;
- Similarly, while many European OEMs are leading innovators, in terms of technological and strategic competencies across software architecture, connectivity and autonomous driving, no European OEMs, at this time, can be considered top innovators, which represents an overdependence risk on technology companies outside the EU;
- With almost half the value of an EV being electronics related, the role of large electronics companies is becoming increasingly important, allowing them to enter the automotive market. This disruptive trend will pick up momentum, thus increasing the competition for EU OEMs;
- With around 17,000 EU SMEs active in vehicle manufacture, carmakers specialising in traditional transmission and internal combustion engine (ICE) component production face major risks. There are only around 20 moving parts in an electric motor compared to over 2000 in an ICE, which also manifests in reduced servicing that will negatively impact the SMEs in the aftersales market;
- The electromobility ecosystem in the EU, unlike the US and China, was a late starter, but the pace of dynamic start-ups is gaining momentum;
- Weaknesses in EV battery supply, raw materials, and associated innovation represent a significant threat to the development of electromobility in Europe;
- Locations with high concentrations of EVs or 'supercharging stations' will be prone to overloading local substations, triggering 'black-outs' short term and costly remedial investment by grid operators, mid-term;
- While EU automotive companies are leading in terms of R&D intensity, the EU must increase ICT R&D, which is a key digitalisation precondition. This challenge will increasingly be exacerbated if the existing STEM trained worker supply gap continues; and
- Although an EV leaves a car showroom with zero emissions, the upstream supply chain associated with the same vehicle has already generated a large carbon footprint.

Opportunities for the EU automotive sector

The COVID pandemic has accelerated the development and sale of EVs while connectivity, digitalisation and other new technologies are creating new 'data-driven' business models whereby 2020 represented a 'tipping point' in the adoption of EVs.

From a broader EU perspective, electrification, smart and shared mobility represent major strides towards environmental sustainability and efficient transportation, enabled to a significant extent by digitalization. The optimal route towards excelling in greening and digitalisation while unlocking the full potential of the EU automotive industry is to regain leadership in the core technologies, especially within the connected and autonomous vehicles (CAVs) segments. Key opportunities include:

- EU automotive industry to showcase that the pace of greening and digitalization is entirely consistent with the political guidelines of the European Commission in general and the EU Industrial Strategy in particular;
- A technologically neutral stance by the EU is, commendably, enabling both the growth of lithium-ion (Li-ion) and hydrogen fuel cells (HFCs) related technologies;
- Europe's regional production systems and value chains act as a conduit through which SMEs, facilitated by demand-driven linkages programmes, can better integrate with GVCs;
- Smart Charging (V1G) and Vehicle to Grid (V2G) technologies can increase the flexibility and efficiency of the existing grid and drive further investment in renewable energy and cross-border transmission to enhance environmental sustainability;
- Consolidating the EUs global lead in sustainability-related technological development while leveraging the ubiquitous presence European carmakers and top tier suppliers have in international markets;
- Electromobility is creating considerable employment, investment, and value-added opportunities. Furthermore, mobility services and new business models are creating a new generation of IT-enabled and monetisation-related digital businesses;
- Multimodality, through enhanced connectivity, enriches consumer choices while CAVs simultaneously increase travel comfort and safety; and
- Employment gains in CAV-related design, testing and manufacturing can help offset job losses within the traditional engine, transmission, cooling, exhaust, and braking systems segments, thereby necessitating up-skilling.

Summary of core findings

By performing a strengths, weaknesses, opportunities, and threats (SWOT) analysis of both electromobility and CAVs in Europe, the broader study findings were substantiated and calibrated. The findings are summarised in Figure 0.1.

Figure 0.1: SWOT assessments for electromobility (left) and CAVs (right) in Europe

Electromobility

Strengths

- Established carmakers and supplier base with strong brand value, technological and financial capacities
- Large and integrated continental consumption market
- Clear and coherent long-term policy framework at the European level
- Highly qualified labor force, leading ecosystem of R&D and training institutions

Weaknesses

- High dependence on established firms, with no relevant newcomers amongst carmakers
- Relatively high dependence on plug-in hybrids and weaker performance in fully electric vehicles sales and innovation
- Unequal infrastructure development between Member States as well as regions and cities
- Low penetration in the Chinese BEV market

Opportunities

- Established presence in international markets, including the high-growth Chinese market
- Ambitious sustainability goals and regulations by the EC and member-states,
- Strong incentives for market growth coming from the EU and lead member-states
- High engagement and priority to the sector in the European industrial strategy

Threats

- Unestablished battery supply base, strong presence, and tradition of Asian firms in battery production
- Dependence on foreign supply of raw materials for battery cell production
- Technological competition from US and Asian OEMs and newcomers
- Regional inequality in terms of production, infrastructure and EV uptake
- Possible mismatch between skills being offered to the established markets and demand from the upcoming electric car sector

CAVs

Strengths

- Established automotive manufacturer and supplier base with strong brand value, technological and financial capacities.
- Strong existing innovation capabilities in automotive and in CAV technologies combined with high R&D intensity and a start-up ecosystem.
- Large and integrated continental consumption market and access to global markets.
- Coherent long-term policy strategies at the European level.

Weaknesses

- Lack of a strong ICT sector and large European digital players impeding access to data, digital ecosystems and important connectivity technologies.
- Apart from largest OEMs lack of sufficient financial capabilities to stem the digital transition alone.
- Lack of venture capital and scale-up funding for start-ups cementing reliance on large OEMs and hindering growth of new innovative companies.
- Lack of digital and software engineering skills within the sector and the wider EU economy.

Opportunities

- Established presence in the European and international markets.
- New digital services open up new business opportunities beyond vehicle sales.
- Political ambitions coupled with regulatory foresight giving the European sector strategic directions and funding opportunities.
- Characteristics of European urban and rural regions providing ample opportunities for new mobility concepts.

Threats

- Increased competition from new entrants and technology companies.
- Interruptions to roll-out of supporting infrastructure (i.e. 5G networks) could slow the deployment of CAVs.
- Dependence on foreign key supporting industries (e.g. semi-conductors, technologies for 5G mobile communication standards)
- Lack of user acceptance and slow uptake of demand in Europe compared to other regions.
- Increased lack of digital skills could lead to an intensified global competition for talent.

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Policy measures

The findings of the SWOT assessment served as a precursor for developing policy measures aimed at enabling the European Parliament to establish an independent view regarding steps and measures that synchronise greening and digitalisation with enabling the automotive industry to regain and sustain global technological leadership in electromobility and CAVs through innovation-driven competitiveness.

For several years the EU has been effectively championing the twin green and digital transition through various guidelines, strategies, action plans, initiatives, directives, and incentives. This strategic and policy framework, in and of itself, is unique globally and thus provides an enabling environment conducive to facing the full rigours of the increasing international competition. Commendably, by scrutinising the 'big picture,' reviewing the automotive supply chain end-to-end, turning the spotlight on skills provision while anticipating and responding to the needs of the automotive industry, most of the policies are in place to help ensure technological leadership and competitiveness.

The study, however, has identified some gaps and scope for further actions that can advance the EU's agenda while also helping the automotive industry in Europe to sustain its role as an engine for sustainable and inclusive economic growth and employment across all Member States. Given that it is the accumulation of the identified policy recommendations that will be most impactful, it is less than optimal to prioritise some recommendations over others.

Figure 0.2: Policy recommendations for the future of the EU automotive sector

Challenges and Opportunities	Policy Options / Recommendations
1. Ensure supply chain resilience for critical raw material (CRM)	Develop and implement CRM plan that: · Complements European Raw Materials Alliance · Establishes R&D alliances to develop next generation of Li-ion batteries · Places heavy emphasis on semiconductor design for EU companies
2. Simultaneously drive the local sourcing and 'greening' agenda	Develop and implement 'end-to-end' automotive supply chain 'greening' plan that: · Rigorously applies emission and CO2 testing 'up-stream' to avoid sourcing strategies creating significant carbon footprints · Guides EU companies through environmentally sustainable checklist when sourcing semiconductors · Showcases European world class EV battery development, production, and recycling (e.g. Northvolt Sweden) prompting new European entrants to follow
3. A greening transition that works for the environment, industry, and workers	Flank mandatory targets, especially within the context of the 'Fit for 55 package' with supporting measures that: · Leverages the Just Transition Mechanism · Provides advanced intelligence enabling all companies in the EU automotive industry to be better prepared and resourced for the twin transitions underway
4. Ensuring infrastructure for EV charging or fuelling meets demand	Accelerate the expansion of the charging and refuelling network for electric and hydrogen-fuelled vehicles across the EU by: · Helping ensure MSs adhere to the oversight provision within the EU's Sustainable and Smart Mobility Strategy and stressing the need for a dramatic increase in fast charging stations · Insisting that infrastructure budget allocations to MSs should set a minimum threshold for funds to be invested directly in EV-related infrastructure · Enabling the EP to facilitate effective dialogue between grid operators, regulators, transport associations and the automotive sector to meet VIG and V2G functionalities and thereby lower a constraint on EV sales
5. Better anticipate and respond to the increasing skills demand	Ensure that digital / STEMs-related skills supply meets the substantive increase in demand by: · Following up on initiatives including DRIVES, the Automotive Skill Alliance and Pact for Skills thereby helping ensure skills supply meets demand · Encourage training in key fields and promote retention of talent while creating fresh talent pools by, for example, attracting more women into STEM sectors · Advising MSs to introduce 'behavioural incentives' that motivate the private sector to increase skills development for their employees
6. Safeguarding data sovereignty	Already a global leader in data protection and privacy, it is essential to respect and protect EU values in the collection, transfer and sharing of data by: · Ensuring that the EP oversees the development of secure European data spaces which are fully compatible with privacy laws · Explaining that the development by most of the European OEMs of their own ecosystems, applications and databases will ultimately lead to fragmentation and thus undermine European competitiveness thereby justifying the case for EU-wide standards for data-enabled services · Capitalising on the Data Act and proposal on access to in-vehicle data by harnessing the best practice expertise which already exists within the EU
7. Enabling European SMEs to better integrate with automotive GVC	While the OEMs shape global value chains, SMEs form the backbone of the automotive industry and thus further intervention programmes are needed to enable SMEs to diversify through accelerated digitalisation by: · Developing the next generation of supplier linkages programmes which are demand driven by OEMs and top tier suppliers · Leverage existing automotive productive and innovation clusters for digitalisation and greening themed matchmaking
8. Facilitating connected and autonomous vehicle technologies	CAV technological developments generally face technical, legal, and public acceptance barriers and within Europe the two most significant barriers are availability of infrastructure to test and roll-out the vehicles and user acceptance. Plans to overcome those barriers should: · Ensure close collaboration between regulators and the automotive industry · Provide regulatory support for large scale testing sequenced with encouraging MSs to fill existing policy vacuums · Avoid fragmentation of efforts and facilitate the coordination of research and innovation testing activities across the EU through the establishment of a European network of living labs

INTRODUCTION

The automotive sector is an important contributor to the European Union (EU) economy. Over 6% of total EU employment is linked to automotive, and the sector's turnover represents over 7% of EU Gross Domestic Product (GDP). At the same time, the automotive sector is the biggest private investor in research and development (R&D)[1]. However, the industry finds itself at a crossroads with various trends changing the industry. In particular, trends related to the:

- Green transition (electromobility, hydrogen fuel cells, etc.); and the
- Digital transition (connectivity, autonomous driving, software etc.).

By themselves, the twin transition is already an enormous challenge for the industry; however, simultaneously, global competition is also intensifying. It is expected that 80% of growth in the global automotive industry will occur outside the EU. This requires not only leading and implementing the twin transition but also doing it in a way where the EU industry remains resilient and can grow in the EU while accessing global growth markets. Therefore, as a third trend, one should add the resilience of the industry and the wider economy in light of increasing global competition, changing business models and interruptions to global supply chains.

This study provides an independent overview of the automotive industrial landscape. Specifically, the study assesses the trends currently reshaping the automotive sector and provides recommendations considering the adequacy and consistency of ongoing and future EU actions. In doing so, the study aims to address the following research questions:

Table 0.1: Research questions for this study

Trends	Research questions
Greening of the industry	• The positioning of the EU industry at the global level in terms of electric mobility; • The state of play of research and innovation in The EU batteries value chains; • The impact of electric mobility and demand-side flexibility on the energy system; • Environmental sustainability, for example, through electromobility or new mobility concepts; and • An overview of the feasibility and time scale of the phasing out of fossil fuel cars and the future role of hydrogen and other gases.
Digitalisation	• The challenges put forward by the emergence of autonomous vehicles, the customers' attitudes towards and acceptance of autonomous and shared vehicles; • Digitalization of the industry, including, for example, autonomous driving or digitally driven new mobility concepts; • The dependence of the EU automotive industry regarding critical raw materials and semiconductors; and • An overview of future trends in terms of smart mobility and the role that artificial intelligence could play.

Trends	Research questions
Resilience and new business models	• The decline of the combustion engine and the consequences for traditional suppliers; • The challenges and opportunities of future trends in sale and maintenance and the consequences for business models (sharing, leasing); • The model of 'using instead of owning' advanced by new connected services; and • The specificity of EU urban configurations and the influence of new modes of urban mobility.
Cross-cutting topics	• Job creation and skills in a rapidly changing industry; • Financing or investment gaps.

This study (carried out in the period June 2021 - September 2021) was commissioned by the Policy Department for Economic, Scientific and Quality of Life Policies in the DG Internal Policies of the Union on behalf of the Committee on Industry, Research and Energy (ITRE) of the European Parliament (EP), to provide an independent expert opinion on the *future of the EU automotive sector.*

The study is structured into six chapters:

- **Chapter 1: Megatrends in the global automotive value chain** – provides an overview over the global and EU automotive sector and how current trends are affecting it;
- **Chapter 2: Greening of the EU automotive sector** – assesses the EU automotive sectors' ability to contribute to the green transition and the sectors' position in areas such as electromobility;
- **Chapter 3: Digitalisation of the EU automotive sector** – analyses the sectors' ambitions in digitalising and its innovative abilities in areas such as connectivity and automated driving;
- **Chapter 4: Changing business models and resilience** – discusses how various technological trends in greening and digitalisation affect the business models of the sector and its overall resilience;
- **Chapter 5: EU level policy responses** – outlines EU policies and strategies relevant for the automotive sector and the twin transition;
- **Chapter 6: Conclusions and recommended policy actions** – summarises the main conclusions and provides recommendations to address the identified gaps.

1. MEGATRENDS IN THE GLOBAL AUTOMOTIVE VALUE CHAIN

KEY FINDINGS

- Automotive is a globalised industry that however thrives on regional clusters with strong linkages between original equipment manufacturers (OEMs) and suppliers.
- OEMs and tier 0.5 (i.e. suppliers taking over responsibility from OEMs for major systems and modules from a vehicle value-creation perspective) and tier-one already have production lines ready for the new generation of electric vehicles (EVs).
- Outward Foreign Direct Investment (FDI) by Chinese EV OEMs increases competition for EU OEMs.
- The COVID pandemic accelerated the development and sale of EVs.
- COVID also increased the importance of digital channels and led to OEMs investing more in agile and resilient global value chains (GVCs) by increasing sourcing regionally.
- The increased electronic content in automotive production is motivating electronic companies to transition into the automotive industry.
- Very significant increase in investment in lithium-ion battery production across Europe in the last two years.
- Connectivity, digitalisation and other new technologies introduce new (data-driven) business models.
- Joint Ventures and collaboration (including with former competitors) continue to increase.
- The twin transition will require the EU automotive sector to adapt to new realities; various EU proposals and initiatives are already in place to address these challenges.

1.1 The Global Value Chain

'The automotive industry will evolve more in the next decade than it has in the previous century…to keep up with the future of mobility, it is not enough to only bring zero emission cars on to the road, we need to invest in technologies that will improve the way we get around and live and we need to develop infrastructures that connect people not only to their destination but also to new opportunities[2].'

1.1.1 Changing GVC dynamics driven by new technologies

The switch from ICE-powered vehicles to EVs was a game-changer prior to the COVID-19 pandemic, and while these traditional power sources will be needed in many markets for the foreseeable future, some prominent brands have already announced an all-electric line up within four years, which profoundly impacts on the automotive GVC. Similarly, trends such as connectivity and autonomous driving have been accelerating the importance of software, data and electronics. These trends will also continue to drive change in the automotive GVC.

[2] Cole, M., 2021. President and CEO Hyundai Motor Europe: BBC Global News.

These new technologies have lowered the barriers to enter the market – specifically, digital technologies in the areas of autonomous driving and connectivity have increased the importance of vehicle software and data.

This disruption has intensified competition by increasing the importance of Information Technology (IT) and electronic manufacturing services (EMS) companies, specifically from large technology companies from the USA and China, which have the financial capabilities to invest in the development of vehicle technologies. These companies have the potential to disrupt the market and the more traditional companies. [3]

New technologies drive new business models - Advanced technological solutions are impacting the future of mobility also more generally. Specifically, in the following areas[4]:

- Cars that are self-aware and provide a connected platform for new business models such as shared mobility concepts leading to OEMs exploring new business areas[5],
- Capacity to bundle new vehicle sales with new subscription-based offerings for charging and ride-share etc.;
- Algorithm-based insurance based on data from connected cars;
- Customer loyalty is less influenced by brand and convenience and more by the value of associated mobility options;
- Accelerated digitalization throughout the entire supply chain; and
- Race for talent competing head-to-head with other technologically advanced sectors, with artificial intelligence (AI) being a common denominator.

The necessity of collaboration - To keep pace with technological developments along with the design, test, and production of new EV transmission modules, regenerative systems and connectivity and autonomous functions, even the top 25 global tier-one suppliers are increasingly seeking to share the R&D and new product cost burden and quick turn-around times needed by forging joint venture partnerships. Joint venturing within the automotive sector is not new, but the accelerated desire for joint ventures to keep pace with technological development and production is a prevailing trend that will continue.

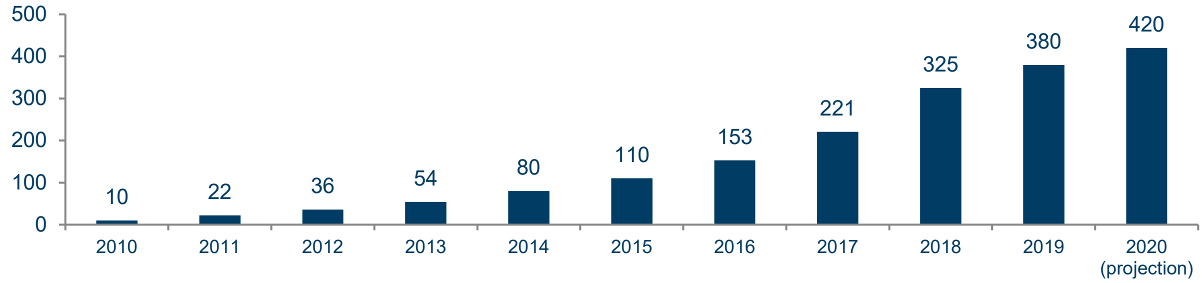
[3] Deloitte, 2017. The Future of the Automotive Value Chain - 2025 and Beyond. at: https://www2.deloitte.com/content/dam/Deloitte/us/Documents/consumer-business/us-auto-the-future-of-the-automotive-value-chain.pdf.

[4] Cubiss J., 2021. The Future of Automotive and Mobility. Forbes. Available at: https://www.forbes.com/sites/sap/2021/05/05/the-future-of-automotive-and-mobility/.

[5] For example, Daimler and BMW created joint ventures for their shared mobility services including for example Share Now, Free Now, Park Now and the mobility platform Moovel in order to compete with digital companies such as Uber. However, recently the companies have become more cautious, reorienting themselves back to their core business of manufacturing vehicles and selling many of their services and mobility apps. See: Hubik, F., 2021, *Ausverkauf bei Mobilitäts-Apps: BMW und Daimler trennen sich von Park Now*., Handelsblatt.

Available at: https://www.handelsblatt.com/unternehmen/industrie/autobauer-ausverkauf-bei-mobilitaets-apps-bmw-und-daimler-trennen-sich-von-park-now/26988330.html.

Figure 1.1: The past decade has witnessed a fortyfold increase in Joint Venture with a sharp focus on electrification and shared mobility (ACES partnerships)



Source: McKinsey & Company 2020. ACES: Autonomous Technologies, Connectivity, Electrification and Shared Mobility;

There are various other topics affecting the global automotive industry. For example, in 2017, Deloitte[6] identified the topics that would have the most impact on the future of the automotive industry. Based on the highest degree of impact and highest degree of uncertainty, the following topics were identified:

- Connectedness of cars;
- Innovation;
- Light-weighting technologies;
- Autonomous driving;
- E-mobility business models;
- Competition for talent;
- Trust in OEMs;
- Role of suppliers; and
- Environmental regulations.

Together with the topics mentioned previously, these will be revisited later in this study as it impacts on the competitiveness of the automotive sector.

It is clear that moving forward, greener consumer preferences and new digital technologies are fuelling disruptive changes along the entire automotive GVC. What is not clear, however, is the extent to which the transformation of the automotive industry can maximise inclusive and sustainable economic benefits in terms of jobs, innovation, value-added, entrepreneurship, trade, investment, eco-friendliness, and optimising gender balance.

1.1.2 A global but regional industry

Automotive has been a global industry for over 100 years. Ford opened its first overseas production plant in Manchester, England, in 1913 and its first plant in Germany in Berlin in 1925. The emergence of regional production systems resulted in regional integration, which, in turn, created opportunities for industrial upgrading in developing countries which has brought with it changes in the relationship between manufacturers, assemblers and suppliers.

[6] Deloitte, 2017. *The Future of the Automotive Value Chain - 2025 and Beyond.* Available at: https://www2.deloitte.com/content/dam/Deloitte/us/Documents/consumer-business/us-auto-the-future-of-the-automotive-value-chain.pdf.

Fast forward to the end of the last millennium. Opportunities were appearing for suppliers in emerging economies to move up in the value chain. In Europe, this has been clearly observed in the Czech Republic, Hungary, Poland, Slovakia, and Romania.

Furthermore, large developing countries like China and India increasingly realised that their very large domestic markets were in and of themselves growth drivers, with China moving into the fast lane earlier than India.

In the first decade of this millennium, three important specificities of the automotive global value chains (GVC) organisation emerged[7], namely:

- The export of finished vehicles to large mature markets was limited by political considerations, which included pressure on OEMs for local production, pressure to attract foreign direct investment and risk of backlash if imported vehicles gain too large a market share;
- The integral nature of the product architecture led to robust 'relational' linkages between original equipment manufacturers (OEMs) and tier-one suppliers, whose role was becoming of increasing importance compared with the past - with tier one suppliers increasingly taking on a design and development role in partnership with OEMs. This led to the creation of tier 0.5 suppliers who work long-term with customers and share product development; and
- On account of the two above-mentioned aspects, the organisation of production remained more regional than global.

Global integration has advanced as firms sought to leverage engineering efforts across products sold in multiple markets, but on the production side, the dominant trend is regional integration with a corresponding gradual investment shift towards locations with lower operating costs. This can be witnessed in countries like Morocco with its tariff-free access to the European Union. In 2017, the Chinese BYD (Buy your dreams) Auto Industry Company signed a Memorandum of Understanding with the Government of Morocco to build a high volume EV car plant[8]. That BYD observed the ease in which both Renault and PSA ramped up high-volume vehicle production and successfully established R&D operations, in the case of PSA, significantly boosted investor confidence. The historic pattern emerging in recent years was of global integration proceeding farthest at the level of buyer-supplier relationship through which tier-one suppliers become more dominant, resulting in local, national, and regional value chains being more embedded with the global organisational structures and business relationships of the largest firms.

This regional dimension will continue to impact the automotive industry and supply chain over the next decade. '**As the consumption of mobility is local by nature, so is the expected adaption of new technologies and mobility patterns**[9]'. Over and above EV propulsion, autonomous driving necessitates an active chassis with a wide range of compensation and safety functions, and thus a large number of new components and systems are needed in this area alone.

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[7] Sturgeon. T. et al., 2011. *Global value chains in the automotive industry: an enhanced role for developing countries?* International Journal of Technological Learning and Development.
Available at: https://ideas.repec.org/a/ids/ijtlid/v4y2011i1-2-3p181-205.html.

[8] The Association of European Vehicle Logistics.
Available at: https://ecgassociation.eu/article/?id=1201.

[9] PWC, 2018. *The Transformation of the Automotive Value Chain.*
Available at: https://www.pwc.de/en/automotive-industry/the-transformation-of-the-automotive-value-chain.html.

1.1.3 Changing global value chain dynamics in the face of COVID-19

While the COVID-19 pandemic throughout 2020 and 2021 has had a devastating impact on the global economy, it also represented a 'reset opportunity' for both government and automotive OEMs to respectively forge new industrial policies and strategies to enhance the resilience of GVCs.

In addition, the stress test provided by the COVID-19 pandemic generated feedback on where policies need to be realigned, strategies adjusted, and integration within the automotive GVCs fortified. Consequently, COVID-19 has influenced megatrends in terms of greening, digitalisation and GVCs.

COVID-19 as an accelerator for EVs – COVID-19 represented an 'accelerator' for the development and sale of EVs, and while the sale of internal combustion engine (ICE) including diesel-powered cars plummeted, the sale of plug-in-hybrid electric cars (PHEVs) and light commercial vehicles reached a record of 2.3 million sold globally in 2020[10]. Indeed, 2020 may well represent the 'tipping point' in the adoption of EVs, based on extensive research.

EVs of all types accounted for six percent of the cars on Europe's roads in 2020,[11] with North America's EV sales in the 'slower lane' compared with the European Union (EU), China, at the country level, continues to lead the world in the adoption of EVs with 1.2 million sold in 2019 and 3.35 million EVs on China's roads by the end of 2020. In addition, this increasing demand for EVs is spiking the demand for EV batteries. In fact, OEMs and suppliers have increased investments during COVID-19 in EV battery production, whereby battery supply chain investment in Q1 2021 was higher than for all of 2020[12].

COVID-19 highlighting the importance of digital channels - McKinsey[13] reported that about 95 percent of all German automotive-related companies put their workforce on short-term work in 2020 at a time when the top 20 OEMs witnessed a collective decline in profits of circa $100 billion, representing a roughly six percent decline in profitability over a two-year period. Before the COVID-19 pandemic, automotive players were uncertain about using digital channels, and some of the traditional OEMs are thus late entrants.

Tesla, on the other hand, is a trend setter. During Q1 of 2020, China experienced an 80 percent decline in overall automotive sales, while Tesla boosted sales by 10 percent by committing to the Chinese market through their new production plant in Shanghai and through the establishment of online sales offers, including contactless test drives and home deliveries.

COVID-19 highlighting the fragility of supply chains - The mantra of 'just-in-time' while just as ubiquitous as ever, is now combined with a 'just-in-case' outlook whereby as the pace of disruption increases, the astute OEMs and suppliers have already started to learn and benefit from this underlying disruption theme. Granted, lessons were learned in the automotive industry from the 2008-2009 financial crisis whereby cost-saving pressures reverberated right along the supply chain, but the COVID-19 pandemic exerted a greater stress test.

More specifically, thirteen or fourteen years on, the change drivers are different and more complex given the fundamental change in consumer behaviour coinciding with the unprecedented availability

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[10] World Economic Forum, 2021. *2020 was a breakthrough year for electric vehicles*. Available at: https://www.weforum.org/agenda/2021/01/electric-vehicles-breakthrough-tesla-china/.

[11] J.P. Morgan, 2020. *The Future is Electric*. Available at: https://www.jpmorgan.com/insights/research/future-is-electric.

[12] Fitch Solutions, 2021. *Batteries Investment Round Up: New Players and Countries Begin to Make Their Mark*. Available at: https://www.fitchsolutions.com/autos/mid-year-update-autos-key-themes-2021-06-07-2021.

[13] Hofstätter. T. et al., 2020. *Reimagining the Auto Industry's Future: It's Now or Never*. McKinsey & Company. Available at: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/reimagining-the-auto-industrys-future-its-now-or-never.

and adoption of advanced technologies, which may represent a double-edged sword, especially for suppliers. On the one hand, those technologies can enhance competitiveness. On the other hand, they can open the door to new entrants to the market, especially in terms of electronic companies transitioning into the automotive sector.

1.2 The EU Automotive Sector

The EU automotive sector is central to the EU economy. It generates a turnover that represents over 7% of the EU GDP[14]**, which totalled around EUR 936 billion in 2020**. The sector plays a major role in the economy through its vast supply chain and generating various business services[15]. Strategically, the EU automotive sector contributes to the EU balance of trade, generating a surplus of EUR 74 billion, thanks to over 5.6 million vehicles exported per year to the rest of the world[16]. Automotive manufacturing alone employs 3.5 million people (over 11% of EU employment in manufacturing)[17], of which 1.2 million are employed in assembly plants, 1.4 million employed with automotive suppliers, and the rest in indirect automotive manufacturing, such as in the production of tyres, gears, and ventilation equipment[18]. All in all, the sector[19] consists of 1.4 million companies[20]. The EU leadership in the automotive sector is due to its capacity to innovate. **It is the biggest private investor in research and development** (R&D) in the EU, with over EUR 62 billion invested in 2019[21]. Of this total, over EUR 25 billion are invested yearly by suppliers, which also produce an estimated two-thirds of the over 9,000 patents filed by the automotive sector.

1.2.1 Regional integration combines global champions and specialised SMEs

As presented in section 1.1.1., **the automotive sector is a tightly regional integrated sector in Europe, which developed for over 100 years**. Stronger economic integration since the turn of the millennium has led emerging economies to move up in the value chain, becoming strategic players in the EU value chain. This trend is visible in countries such as Czechia, Hungary, Poland, Slovakia, and Romania, which joined countries historically central for the automotive industries such as Germany, Sweden, France, Italy, and Spain. In 2019, close to 19.9% of motor vehicles globally were produced in one of the 186 automobile assembly and production plants located in the EU (see Figure 1.2).

14 European Commission, 2021. *Automotive Industry*. Available at: https://ec.europa.eu/growth/sectors/automotive_en.

15 Ecorys, CEPS, 2021, *Impacts of the COVID-19 pandemic on EU industries*, European Parliament, Policy Department for Economic, Scientific and Quality of Life Policies Directorate-General for Internal Policies. Available at: https://www.europarl.europa.eu/RegData/etudes/STUD/2021/662903/IPOL_STU(2021)662903_EN.pdf.

16 ACEA, 2020. *EU Exports of motor vehicles*. Available at: https://www.acea.auto/figure/eu-exports-of-motor-vehicles/.

17 European Commission, 2021. *Automotive Industry*. Available at: https://ec.europa.eu/growth/sectors/automotive_en.

18 ACEA, 2021. *Pocket guide 2020-2021*. Available at: https://www.acea.auto/uploads/publications/ACEA_Pocket_Guide_2020-2021.pdf.

19 Including inter alia parts and accessories supplier, batteries, dealerships, part retails, and logistics.

20 European Commission, 2020, *Identifying Europe's recovery needs*. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020SC0098(01)&qid=1591607109918&from=IT.

21 ACEA, 2021, *R&D investments by top 10 industrial sectors in the EU*. Available at: https://www.acea.auto/figure/rd-investment-by-top-10-industrial-sectors-in-eu/.

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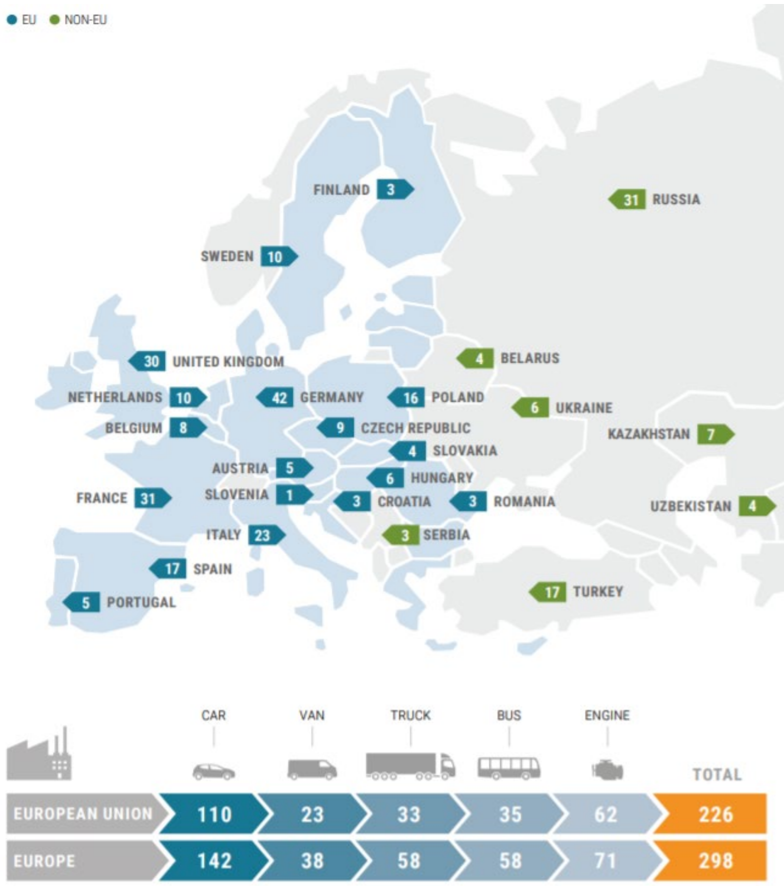
Figure 1.2: Automotive factories across Europe



Source: ACEA, 2021, Pocket guide 2020-2021.

Europe's automotive industry consists of some of the leading automakers worldwide, including Volkswagen (1^{st} by revenue globally in 2020), Daimler (3^{rd}), BMW (7^{th}), Stellantis (9^{th})[22], with assembly plants across the EU. Foreign carmakers also have assembly plants inside the EU, such as Hyundai in the Czech Republic. Other than being home to the biggest car manufacturers in the world, the EU hosts some of the biggest automotive suppliers in the world. In 2019, when assessed by revenue, Bosch was the biggest player globally, followed by Continental as second, ZF Friedrichshafen as fifth, Michelin as ninth and Valeo as tenth[23].

A limited number of major companies of global significance are supported by a multitude of Small and medium-sized enterprises (SMEs) and midcaps[24].

[22] Statista, 2021, *Revenue of leading automakers worldwide in 2020*.
Available at: https://www.statista.com/statistics/232958/revenue-of-the-leading-car-manufacturers-worldwide/.

[23] Berylls, 2021, *The World's 100 biggest automotive suppliers in 2019*.
Available at: https://www.berylls.com/wp-content/uploads/2020/07/202007_BERYLLS_Study_Top_100_supplier-2019_EN.pdf.

[24] European Commission, 2020, *Identifying Europe's recovery needs*.
Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020SC0098(01)&qid=1591607109918&from=IT.
Available at:
https://eur-lex.europa.eu/legalcontent/EN/TXT/PDF/?uri=CELEX:52020SC0098(01)&qid=1591607109918&from=IT.

In 2018, in the EU27, it was estimated that around 17,000 were active in the manufacture of vehicles. Of these, 2,757 are based in Germany, 2,167 in Italy, 1,717 in Poland, 1,623 in Spain, 1,611 in France, and 1,089 in Czechia[25].

The regional integration of the automotive GVC discussed in the previous section can also be found in the EU, where **automotive is the most integrated ecosystem in intra-EU value chains**. Over 45% of its production depends upon cross-border value chains within the EU[26]. This intra-EU value chain brings together vehicle manufacturing, automotive suppliers, manufacturers of motor batteries, electrical equipment, tyres, suppliers of raw materials and car use services. A very large number of SMEs, highly specialised in specific segments of the value chain, such as exhausts, interior fittings, precision tooling, are located in Member States like Hungary, Czech Republic, but also France, Spain and Italy, where they play a fundamental role for the ecosystem[27]. Figure 1.3 presents the number of jobs per sector across the value chain of the EU automotive sector.

Figure 1.3: Employment creation in the EU automotive value chain

Source: CLEPA, 2021, Automotive supplier's employment footprint. Available at:https://clepa.eu/who-and-what-we-represent/suppliers-eu-employment-footprint/employment/.

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25 53% of the total EU car manufacturing employment is located in Germany, 10% in France, 7% in Italy, 6% in Spain, 5% in Sweden. Source: Eurostat. Eurostat, 2021, *Annual enterprise statistics for special aggregates of activities*. Available at: https://ec.europa.eu/eurostat/databrowser/bookmark/51719037-6ba5-4dce-8fc3-13781a2273c0?lang=en.

For data disaggregated at the regional level see: *Eurostat, 2021*, SBS data by NUTS 2 regions and NACE rev. 2.

Available at: https://ec.europa.eu/eurostat/databrowser/bookmark/7878b4dc-1c33-4dc4-a6b5-32a32aafcd52?lang=en.

26 European Commission, 2020, *Identifying Europe's recovery needs*. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020SC0098(01)&qid=1591607109918&from=IT.

27 European Commission, 2020, *Europe's moment: Repair and Prepare for the Next Generation*. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020SC0098(01)&qid=1591607109918&from=IT.

While manufacturing of vehicles is concentrated in a few Member States[28]**, other Member States have prominent roles in the value chain**. This is due to the fact that western European car manufacturers outsourced parts of their supplier network and manufacturing to Central and Eastern European Member States, where labour costs are lower. Until now, according to the European Centre for Vocational Training, outsourcing to Eastern Europe assembling and machine operation activities is still more attractive than fully automating processes. Figures on employment in the car bodies, parts, and tyres manufacturing industry suggest that Member States like Poland, Czech Republic, Slovakia, Hungary, and Romania are key for the sector. These countries account for 47% of total employment, compared to 43% accounted for by more mature supplier markets such as Germany, France, Italy, and Spain[29]. Furthermore, a report by McKinsey maintains that that central and eastern European markets offer untapped potential for the development of competitive automotive R&D in the region[30].

Given the aforementioned tight integration of the sector, only focusing on the European or national level risks overlooking the importance of the sector for certain regions, such as Bavaria, Baden-Württemberg, and Niedersachsen in Germany or Piedmont and Lombardy in Italy. This is especially important as car manufacturers and suppliers tend to form strong clusters. Box 1 presents the importance of automotive for specific regions of the EU.

Box 1.1 Examples of manufacturing clusters in the EU

Germany: manufacturing jobs transitioning toward digital and electrical mobility

A study by the German Ministry of Economics published in 2019 foresees that by 2030, electrification of vehicles could lead to loss of employment in car manufacturing of around 40,000 people in Bavaria (home to BMW and Audi), 35,000 in Baden-Württemberg (Daimler and Porsche), and 25,000 in Niedersachsen (VW). As powertrain is the most labour-intensive component of a car, its move toward electrification could potentially strongly impact employment in those regions (See Section 2.1.2 for coverage of the employment impacts of electrification). Nevertheless, a CLEPA analysis of Foreign direct investments suggests that growth clusters in electronics, software and IT components will create around 35,000 jobs in Brandenburg and Sachsen.

Italy: manufacturing clusters faced with massive layoffs

Almost 70% of employment in the automotive supply chain in Italy is concentrated in the regions of Piedmont and Lombardy. Around 45% of those jobs revolve around the production of parts for powertrains and transmission, which means they will be greatly impacted by the electrification of the sector. Nevertheless, currently, electronics only generates 5% of the revenues of the Italian suppliers, which suggests that radical changes need to be made in the coming years to absorb the employees that will be made redundant in the near future.

Sources: BMWI, 2019 report. Available at: https://www.bmwi.de/Redaktion/DE/Publikationen/Studien/automobile-wertschoepfung-2030-2050.pdf?__blob=publicationFile&v=16.
Automotive employment footprint portal. Available at: https://clepa.eu/who-and-what-we-represent/suppliers-eu-employment-footprint/regional-dimension/.

[28] Cedefop, 2021, *Automotive industry at a crossroads*. Available at: https://skillspanorama.cedefop.europa.eu/en/analytical_highlights/automotive-industry-crossroads#_the_rise_of_european_automotive_industry.

[29] Ibid.

[30] McKinsey, 2021, *Rethinking European automotive competitiveness: The R&D CEE opportunity*. Available at: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/rethinking-european-automotive-competitiveness-the-r-and-d-cee-opportunity.

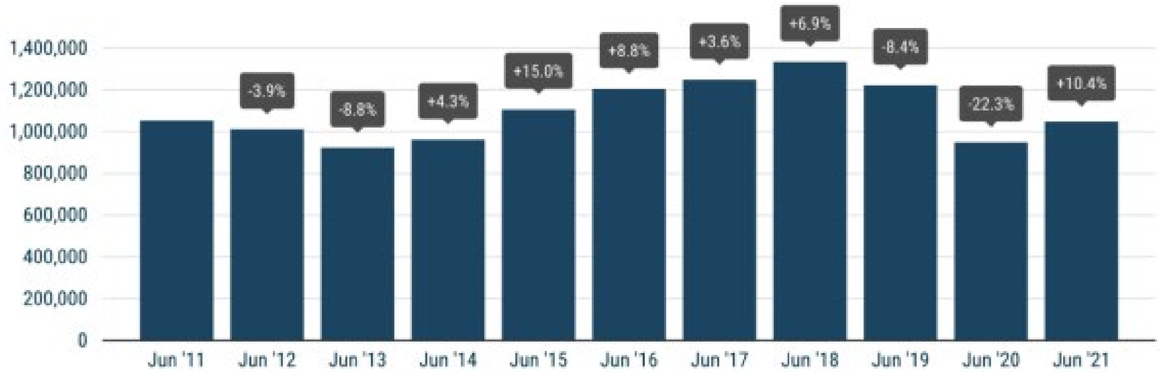
1.2.2 The impact of COVID-19 on the EU automotive sector

As identified by the European Commission (EC)[31], **the automotive sector has been one of the industries hit the hardest by COVID-19 during the first wave**. This is in part due to the supply chain disruptions that followed the shutdowns in China[32] and, most prominently, to the containment measures adopted across Europe between March and May 2020. In the first half of 2020 alone, the EU automotive sector suffered a loss of production of 3.6 million vehicles, which corresponds to a loss of EUR 100 billion. Several carmakers had to be bailed out due to liquidity issues[33]. Moreover, the widespread use of furlough schemes did not prevent the announcement of several plant closures and job losses for both manufacturers and suppliers[34].

Despite the negative impacts of COVID-19, a recent study commissioned by the European Parliament[35] **maintains that the most likely scenario of recovery for the EU automotive sector is U-shaped.** The EU passenger car market contracted by 23.7% in 2020 compared to 2019, which corresponds to 9.9 million units in 2020.

Due to smaller production capacity and a decrease in consumer confidence, car sales in the EU continued declining into 2021. Figure 1.4 indicates that in June 2021, although the number of car registration is growing compared to the same period in 2020, pre-COVID-19 levels have not been reached.

Figure 1.4: New passenger car registrations in the EU



Source: ACEA, 2021, New passenger car registrations, European Union.
Available at: https://www.acea.auto/files/20210716_PRPC_2106_FINAL-1.pdf.

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[31] European Commission, 2020. *Identifying Europe's recovery needs.* Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020SC0098(01)&qid=1591607109918&from=IT.

[32] Accenture, 2020, *COVID-19: Impact on the Automotive Industry*. Available at: https://www.accenture.com/acnmedia/PDF-121/Accenture-COVID-19-Impact-Automotive-Industry.pdf.

[33] FCA and Renault received state aid under the Temporary Framework to support the economy in the context of the COVID-19 outbreak.

[34] European Commission, 2021. Proposal for a Regulation amending Regulation (EU) 2019/631 as regards strengthening the CO2 emission performance standards for new passenger cars and new light commercial vehicles in line with the Union's increased climate ambition. Available at: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52021PC0556. Footnote 105 on pag. 78 enumerates plants operated by car manufacturers such as Nissan, Renault, Bridgestone, Continental.

[35] Ecorys, CEPS, 2021, *Impacts of the COVID-19 pandemic on EU industries*, European Parliament, Policy Department for Economic, Scientific and Quality of Life Policies Directorate-General for Internal Policies. Available at: https://www.europarl.europa.eu/RegData/etudes/STUD/2021/662903/IPOL_STU(2021)662903_EN.pdf.

The EU automotive sector is central for the whole EU economy. Notwithstanding the current strong positioning globally of EU automotive manufacturers, and the measures introduced for the recovery of the sector after the COVID-19 pandemic**, the industry is facing three structural challenges: 1) the greening of the industry; 2) digitalisation; and 3) increasing global competition**.

Electrification will, inter alia, reduce assembly costs (if excluded the production of battery cells, the total number of workhours needed for components is 15%-30% lower for electric vehicles)[36] [37], whereas self-driving connectivity will create new markets and services relying on computing systems and data analysis. To address those transformations, huge investments are necessary[38]. In order to succeed, investments will also be needed in the associated infrastructure and in reskilling the workforce. All those factors are forcing industrial players to find new solutions[39], adapt production, and establish themselves as leaders amid intense global competition.

1.2.3 Leading the twin green and digital transition

The EU automotive sector will experience in the coming years massive structural changes if it wants to remain a global leader. Adapting to new climate change mitigation goals and ensuring the development, deployment and uptake of digital technologies will be key in the future global positioning of EU automotive industries. Currently, the European Commission launched various proposals and initiatives addressing those challenges.

The European Parliament will have a central role in shaping how future initiatives and legislation could support the automotive industry to become greener and more digital. Among the key proposals that will be further elaborated in Chapter 5, we bring attention to:

- **EU industrial strategy [COM(2020) 102] and its update of 2021 [COM(2021) 350]**, which have an overarching goal of guaranteeing that the EU retains global leadership in the upcoming decades while fostering the green and digital transformations of its economies. Noteworthy is the inclusion of automotive as one of the key ecosystems for the EU industrial leadership;
- **The EU Green Deal [COM(2019) 640] and the recent Fit for 55 package [COM(2021) 550]**, which aim at transforming the EU into a carbon-neutral economy in the coming decades. Attention is put to the automotive sector, both in terms of limiting vehicles' emissions and in terms of improving the circularity of vehicles and batteries (this last aspect is central in the Circular Economy Action Plan [COM(2020 98]);
- **EU proposals on supporting the digitalisation of the automotive sector**. EU proposals aim both at developing critical infrastructure for automated and connected vehicles, such as the 5G action plan [COM(2016) 588], and to facilitate the development and deployment of automated and connected vehicles. This can be done, inter alia, by facilitating the sharing of data between industrial actors, as proposed in the EU Data Strategy [COM(2020) 66], which includes, among others, the creation of a European Common Mobility Data Space;

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[36] Herrmann, F. et al., 2020, *Auswirkungen von Elektromobilität und Digitalisierung auf die Qualität und Quantität der Beschäftigung bei Volkswagen*. Available at: http://publica.fraunhofer.de/eprints/urn_nbn_de_0011-n-6154803.Pdf.

[37] Küpper, D, et al, 2020. *Shifting Gears in Auto Manufacturing*. Available at: https://web-assets.bcg.com/fd/de/20c24ec2407d9622175e45e84a2c/bcg-shifting-gears-in-auto-manufacturing-sep-2020.pdf.

[38] Volkswagen Group alone will invest EUR 75 billion until 2025 for electrification and digitalisation.

[39] McKinsey, 2020, *Reimaging the auto industry's future it's now or never*. Available at: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/reimagining-the-auto-industrys-future-its-now-or-never.

- **Industrial alliances for the developments of key technologies**, such as on batteries, clean hydrogen, processors and semiconductors, also in light of possible strategic dependencies that hinder the EU's capabilities of truly becoming a global leader in the development of those key technologies; and
- **Plans for re- and up-skilling workers**, such as the European Skills Agenda [COM(2020) 274]. Such plans are key in light of the twin transitions, which is bound to reshape the needs of EU industries and – if not supported accompanied properly – might lead to large-scale mismatches in the workforce, with consequent high unemployment rates among workers of the automotive sector.

2 GREENING OF THE EU AUTOMOTIVE SECTOR

KEY FINDINGS

- Europe has taken the world lead in EV penetration in 2020. Given current environmental regulations and incentives, the market should continue to grow in this decade, making Europe one of the most promising markets for EVs.
- Market barriers to EV diffusion are still significant but reducing quickly, with consumers becoming increasingly inclined to buy electric vehicles.
- OEMs have committed to ambitious electrification investments and goals for the decade. The number of EV models available in the European market is set to increase sharply throughout the decade, with European OEMs taking the lead.
- Currently, European OEMs (and many suppliers like ZF Friedrichshafen AG) are still relying heavily on PHEV technology, which has weaker long-term perspectives compared to BEVs. Most European carmakers are lagging in BEV innovation, where they are being severely challenged by Tesla, Asian OEMs and newcomers.
- BEV value chains are probably not significantly less labour-intensive than ICE ones when battery production is considered. They are, however, quickly shifting the demand for skills towards researchers, engineers and technicians with electrical, electrochemical, mechatronic, software and industrial skills.
- Battery packs are the main component of EVs and Europe is advancing fast in lithium-ion battery cell production. Most existing projects are being led by the current Asian market leaders but European firms, some of them newcomers partnering with OEMs, are expected to have a relevant share. Challenges remain in value chain sustainability and resilience, sourcing of raw materials and recycling.

2.1 Electromobility

The recent market shift towards electric vehicles (EVs) in Europe has been impressive. In 2020, Europe surpassed China to become the biggest market in the world in both the number of EVs sold and the share of EVs in total car sales. In that year, despite the contraction of overall car sales in Europe, EV registrations more than doubled to 1.4 million and reached 10% of the market, while this number stood at 6% in China and 2% in the US[40]. In 2021, EVs are continuing their impressive growth in Europe and reached 15% of accumulated sales until May, which continues to give Europe a comfortable world lead in the share of EVs[41] [42].

[40] IEA, 2021, *Global EV Outlook 2021 - Accelerating ambitions despite the pandemic*. Available at: https://www.iea.org/reports/global-ev-outlook-2021.

[41] Kane, M., 2021, *Europe: Plug-In Car Sales Almost Quadrupled in May 2021*, INSIDEEVs. Available at: https://insideevs.com/news/517232/europe-plugin-sales-may-2021/.

[42] Kane, M., 2021, *China: Plug-In Electric Car Share Increases To 12% In May 2021*, INSIDEEVs. Available at: https://insideevs.com/news/516858/china-plugin-car-sales-may2021/.

Also in China EVs came up with high growth rates. Until July 2021, over 1.3 million passenger plug-in cars were sold, which corresponds to 12% of the total market[43].

The intensification of some market and regulatory trends - including lower emission limits coming into force in 2025 and 2030, combined with the maturing of the technology and investments undertaken by the OEMs - largely point to a favourable market scenario for the decade, with EVs gradually replacing internal combustion engines (ICEs) on the roads.

This section presents an overview of important consequences of this movement. We start by covering the evolving strategy of carmakers in this context. Following Porter's diamond model, we analyse the factor conditions of the industry, highlighting the role of skills and raw materials for the upcoming electric car sector. We then explore the changing demand patterns that have been propelling EV diffusion and, lastly, explain the effects over the value chain, especially regarding batteries, which are the single most important component of EVs.

We define EVs as both fully and partially electricity-powered cars: Battery Electric Vehicles (BEVs) and Plug-in Hybrids (PHEVs), the latter of which rely on ICEs for most of their autonomy. Nonetheless, our focus remains on the former as we see PHEVs largely as a transition technology.

2.1.1 Firm strategy, structure and rivalry

The strategy of European and International OEMs for electromobility has been directly influenced by the regulatory emission requirements set by the EC for the sales of new cars in Europe. These requirements, especially the more stringent limits determined for 2020/2021 and thereafter, have forced the sector to embrace EVs as the only solution for compliance. The first EC regulation was adopted in 2009, setting a target of 130 g/km of CO_2 for the fleet average (based upon the NEDC laboratory test) to be reached by 2015[44]. However, this regulation was not enough to push the car industry to fully commit to EVs because all major carmakers were able to comfortably achieve the relatively soft target, some several years before the deadline, while keeping the share of EVs in the market at marginal levels.

Several factors explain the sector's easiness in achieving these targets, such as the increase in the share of diesel cars and the financial crisis, which caused a temporary reduction in the average size and weight of cars, and the increase in the gap between emissions in laboratory tests and emissions in real-world conditions. In fact, the 2015 targets would not have been achieved had this gap remained stable at the 2009 levels[45]. Carmakers' main strategy to reach the 2015 regulatory levels appears to have been finding ways to reduce internal combustion engines (ICEs) lab test results by using technologies that have a much larger impact in the laboratory than in real-world driving conditions, e.g. stop-start systems.

[43] Kane, M., 2021, *China: Plug-In Car Sales Almost Set A New Record In July 2021*, INSIDEEVs. Available at: https://insideevs.com/news/527614/china-plugin-car-sales-july2021/amp/.

[44] This regulation followed the failure of the Voluntary Agreements between the EU and the car industry that failed to reach the level of 140 g/km of CO_2 set for 2008. In fact, in 2008, the industry average remained at 153 gCO_2/km in the laboratory and much higher in real-world conditions.

[45] Transport and Environment, 2019, *How car makers can reach their 2021 CO2 targets and avoid fines*. Available at: https://www.transportenvironment.org/sites/te/files/publications/T%26E_201909_Mission%20possible_vF.pdf.

This initial resistance in increasing the offer of EVs relates to the fact that carmakers have generally not been able to make profits from their sales, especially in the case of BEVs.[46] On the contrary, the heavier and more polluting SUV segment remains the most dynamic and profitable segment of the car market. The previous strategy, however, was soon exhausted and showed itself insufficient to achieve the regulatory levels determined by the European Commission for 2020/2021 and beyond. As it became clear that the regulatory fines for breaching the CO_2 emission limits would far exceed the cost of selling more EVs, the European car industry had no option but to embrace electric cars and accelerate the electrification of its fleet.[47]

Box 2.1: EU emission objectives in transportation

Transportation and greenhouse gas emissions in the EU

The European Union is the world's third-largest emitter of greenhouse gases. In 2018, domestic and international transport accounted for 29% of total economy-wide emissions of greenhouse gases in the bloc, with passenger cars (15%) and heavy-duty vehicles (5%) being the largest contributors. While emissions in all other sectors have been reduced by 32% since 1990, in transport they have grown by 33%, being the only major sector where emissions have gone up during the period.

The European Commission has set out the objective of leading the world in the transition to a carbon-neutral economy and established a goal of net-zero economy-wide emissions by 2050. The automotive sector's central role in this agenda is clear in the European Green Deal, which calls for a 90% reduction in transport emissions by 2050. Simultaneously, estimations by International Council for Clean Transportation indicate that the current policies would only deliver tailpipe emission reductions of 24% by 2030 and 53% by 2050. For heavy-duty vehicles, CO_2 emissions would decrease by only 9% by 2030 and 19% by 2050 relative to 2020.

The Commission is now revisiting its post-2021 CO_2 standards for cars and vans in mid-2021 and for trucks and buses in 2022 to achieve these targets. In the scenarios simulated by the ICCT, reaching the Commission's goals would demand significantly more stringent emission limits than the current ones in 2030 and a commitment to zero-emission light-duty vehicle sales by 2035 and no later than 2040. Given the current political context, it is becoming increasingly clear that the European automotive sector should prepare for a complete phase-out of ICE and PHEV vehicles sales by 2035/2040.

Sources: The ICCT, 2021a, Transport could burn up the EU's entire carbon budget. Available at https://theicct.org/blog/staff/eu-carbon-budget-apr2021 and ICCT, 2021b.
The role of the European Union's vehicle CO2 standards in achieving the European Green Deal. Available at: https://theicct.org/publications/eu-vehicle-standards-green-deal-mar21.

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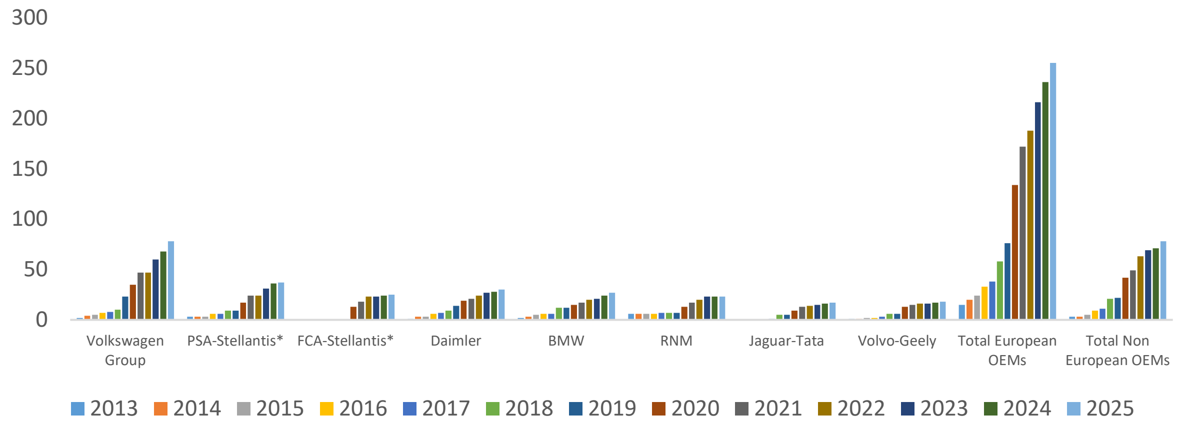
[46] McKinsey, 2019, *Making electric vehicles profitable*. Available at: https://www.mckinsey.com/~/media/McKinsey/Industries/Automotive%20and%20Assembly/Our%20Insights/Making%20electric%20vehicles%20profitable/Making-electric-vehicles-profitable.pdf.

[47] JATO calculated these costs at approximately EUR 34 billion for the entire industry had the average emission levels of 2019 been kept until the end of 2021. See JATO, 2019, *2021 CO2 targets would generate €34 euros in penalty payments within Europe*, Available at: https://www.jato.com/2021-co2-targets-would-generate-e34-billion-euros-in-penalty-payments-within-europe/.

a. The new strategy of OEMs for 2020/2021 and beyond

All European carmakers are set to increase widely the offer of EVs in the coming years, with the Volkswagen (VW) group leading the way (see Figure 2.1 below). This change in strategy is also reflected in the long-term goals of the industry, with almost all OEMs public committing to ambitious electrification goals until 2030. According to the International Energy Agency[48], VW, Daimler, Volvo, and Stellantis have all committed to increasing the participation of EVs in car sales to at least 50% by 2030, while Renault and BMW have announced different, although not necessarily less ambitious, goals. All large OEMs have committed to significant investment in EVs in the coming years.

Figure 2.1: Number of EVs (PHEVs and BEVs) models launched and planned until 2025 by OEM group in Europe.



* PSA and FCA completed a merger in 2021 to form the Stellantis conglomerate.
Source: Transport & Environment (2019).

This movement has translated into an explosion in the offer of EVs in the European market in 2020, with many more models expected for 2021 and beyond. Figure 0.1 shows the planned offer of BEVs and PHEVs in Europe until 2025, compiled by Transport & Environment in 2019[49]. It shows that 2020 and 2021, the years the new mandatory emission limits kick in, represent a breakpoint in the growth speed of EVs in Europe, with a noticeable jump in the number of available EVs. European brands appear well-positioned relative to non-European OEMs and account for a wide majority of the models available in Europe. Renault-Nissan-Mitsubishi (RNM), Volvo and Jaguar are treated here as European OEMs due to their strong production and R&D footprint in Europe, although the latter two are controlled by the Chinese group Geely and the Indian conglomerate Tata, respectively.

As cited in the Introduction to this section, **the consequent market shift towards EVs in the European market has been monumental.** This movement was greatly facilitated by the enabling of stronger subsidies for EVs in the context of green recovery packages during the Covid-19 crisis, notably in Germany, France and Italy[50]. In 2020, Europe, as stated, surpassed China as both the biggest market for EVs in the world and the biggest share of EVs in total car sales.

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48 IEA, 2021, *Global EV Outlook 2021 - Accelerating ambitions despite the pandemic*. Available at: https://www.iea.org/reports/global-ev-outlook-2021.

49 The figure also contains numbers for Fuel Cell Electric Vehicles (FCEVs) but there represent a very small fraction and no more than 14 models are expected until 2025. Announcements and goals are updated frequently in the industry but the graph largely reflects the trends of the sector for the coming years.

50 IEA, 2021, *How global electric car sales defied Covid-19 in 2020*. Available at: https://www.iea.org/commentaries/how-global-electric-car-sales-defied-covid-19-in-2020.

These levels are high but likely insufficient to reach the regulatory requirements set for the new EU 'Fit for 55' legislation, which indicates EV sales will have to expand more in the coming years.

b. The European way: between BEVs and PHEVs

A remarkable aspect of the strategy of European carmakers for EVs in the next 10-15 years is that it relies on a balanced sales mix between BEVs and PHEVs. This is in clear contrast with the rest of the world, where BEVs largely dominate the market. PHEVs are widely seen as a transitional technology by the industry to help for compliance with emission limits in the short- to medium-term[51]. By means of the so-called super-credits, the current regulation offers strong incentives for carmakers to cushion the costs of expanding electric cars by promoting PHEV sales, which contain relatively small batteries and are more profitable. It, therefore, comes as no surprise that PHEV sales have been growing faster than BEVs in Europe, answering for 54% of the EV market until June 2021, while in China, 83% of the market in 2021 has been occupied by BEVs[52,53].

The penetration of PHEVs means a *de facto* postponement of the electric mobility transition since these cars still rely primarily on ICEs, which could mean a disadvantage for Europe in the BEV adoption race. However, this trend will most likely *not* continue in the coming years, as several factors point to limited space for further PHEVs gains over BEVs, such as:

- The reduction of regulatory incentives for PHEV in 2025 and 2030 when the Zero and Low Emission Vehicles (ZLEV) benchmarks are set to kick in. These new rules are set to treat PHEVs less favourably than BEVs when awarding regulatory credits;
- Most carmakers appear to indeed understand PHEVs as a transition technology and are setting goals that suggest a gradual transition to BEVs as the long-term goal.[54] In fact, releases of new PHEVs models peaked in 2020 and will grow much slower than BEVs thereafter[55], indicating a stronger long-term bet in fully electric cars;
- PHEVs are coming under renewed scrutiny recently due to their low electric autonomy and much higher real-world emissions than those indicated in lab tests[56]. This pressure is set to only increase in the coming years, especially if this class of EVs continues to make gains at the expense of BEVs. The UK, for example, has already rolled back subsidies for PHEVs, while Germany is explicitly considering changing PHEV subsidy policy[57]; and

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51 Transport & Environment, 2019, *Electric surge: Carmakers' electric car plans across Europe 2019-2025*. Available at: https://www.transportenvironment.org/publications/electric-surge-carmakers-electric-car-plans-across-europe-2019-2025.

52 Kane, M., 2021, *Europe: Plug-In Car Sales Almost Quadrupled in May 2021*, INSIDEEVs. Available at: https://insideevs.com/news/517232/europe-plugin-sales-may-2021/.

53 Kane, M., 2021, *China: Plug-In Electric Car Share Increases To 12% In May 2021*, INSIDEEVs. Available at: https://insideevs.com/news/516858/china-plugin-car-sales-may2021/.

54 IEA, 2021, *Global EV Outlook 2021 - Accelerating ambitions despite the pandemic*. Available at: https://www.iea.org/reports/global-ev-outlook-2021.

55 Transport & Environment, 2019, *Electric surge: Carmakers' electric car plans across Europe 2019-2025*. Available at: https://www.transportenvironment.org/publications/electric-surge-carmakers-electric-car-plans-across-europe-2019-2025.

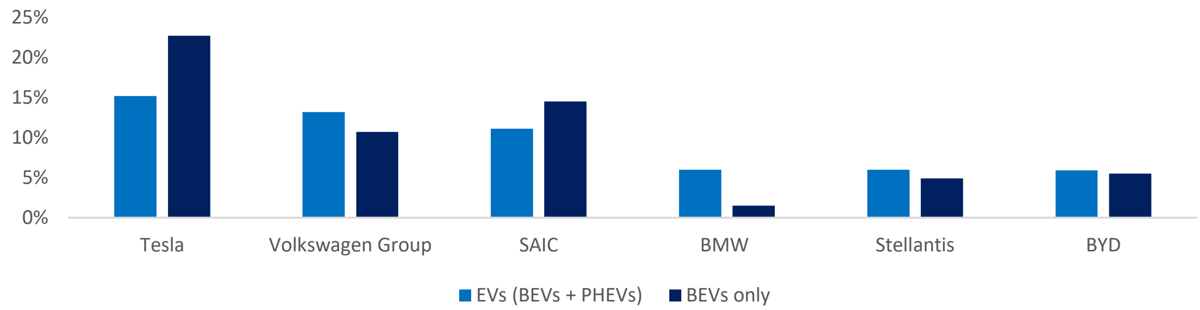
56 Transport & Environment,2021, *PHEVs and the car CO2 review: Europe's chance to tackle fake* electrics. Available at: https://www.transportenvironment.org/publications/phevs-and-car-co2-review-europe%E2%80%99s-chance-tackle-fake-electrics#:~:text=electrics%20%7C%20Transport%20%26%20Environment-,PHEVs%20and%20the%20car%20CO2%20review%3A%20Europe's%20chance%20to%20tackle,million%20units%20sold%20in%202020.

57 McKinsey, 2020, *McKinsey Electric Vehicle Index: EV Market Trends & Sales*. Available at: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/mckinsey-electric-vehicle-index-europe-cushions-a-global-plunge-in-ev-sales.

- Finally, most projections indicate that electric car technology is set to mature around 2025, when the cost of batteries will have fallen enough to make BEV sales prices competitive relative to ICEs in the mid-segment of the market. This development will bring the segment closer to economic maturity, paving the way for an expansion of BEVs that is less dependent on subsidies and policy.

Despite these overall trends, which we believe will be dominant, it is also important to highlight important developments playing in the opposite direction, and that could favour the presence of PHEVs for a longer period, such as the lack of an appropriate charging infrastructure and improvements in the electric range of PHEV models, some of them reaching 100km or more, which should make them more attractive for electric use.

Figure 2.2: World market-shares of top 6 OEM groups in EV sales in 2021 until June



Source: Cleantechnica, 2021.[58]

c. Most European OEMs lag in BEV innovation

European carmakers widening offer of both BEV and PHEV models has resulted in a leading position in the world's EV market in 2021, although Tesla maintains a commanding position internationally with its Model 3. Figure 0.2 shows that VW Group, BMW Group and Stellantis are all well-positioned in the international EV market in 2021. However, European OEMs' situation is significantly weakened when only BEV technology is considered. Chinese brand SAIC and Tesla have their share significantly improved, while BMW posts quite small BEV sales. Daimler, although not shown, shares this PHEV dependence with BMW.

Indeed, except for the VW Group, European OEMs remain followers in the BEV technological race. According to the Center of Automotive Management (CAM) latest ranking of innovative strength[59], which is based on the compilation of 291 recent innovations in the field of electromobility, Tesla remains the leader, followed closely by the VW Group. BYD (China) and Hyundai (South Korea) are classified as Fast Followers, while all other European OEMs lag significantly. Important carmakers such as Daimler and BMW not only remain behind but have made little recent progress.

The five top-selling automobile manufacturer groups contribute to more than half of the global sales of battery-electric cars. CAM predicts a further consolidation of the sector in the coming years due to the major transformational issues in the industry, of which many are approached in this report.

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[58] Cleantechnica, 2021, *Tesla Model 3 & Model Y Take #1 & #2 In World Record Month For Electric Sales!*. Available at: https://cleantechnica.com/2021/08/01/plugin-vehicles-have-record-month-globally-in-june-tesla-model-3-model-y-take-1-2/.

[59] Center for Automotive Management, 2021, The most innovative automobile manufacturers of battery electric vehicles (BEV), Feb 4, 2021.

The recent creation of Stellantis by the merger of PSA and FCA is a first example of this process. The strength of innovation will be increasingly important for survival and economic success.

Despite the recent progress in the offer of models and in sales, it is clear European manufacturers must still boost their innovation performance as lead novelties are coming not only from Tesla and established Chinese OEMs but can also be expected from newcomers such as Lucid Motors (US), Nio and Xpeng (China).

Table 2.1: CAM 2020 ranking of OEM BEV Innovation Strength

Rank	OEM	Innovation Strength	2021 Trend	Classification
1	Tesla	159.4	↑	Top Innovator
2	Volkswagen Group	122.6	↑	Fast Follower
3	BYD	70.6	→	Fast Follower
4	Hyundai Group	58.2	→	Fast Follower
5 - 15	**In descending order:** Renault, GM, Volvo-Geely, BAIC, PSA-Stellantis, SAIC, Daimler, GreatWall, BMW, FCA-Stellantis, Jaguar-Tata	41.4 -15.7	-	Followers
16 - 24	**In descending order:** Nissan, Ford, Nio (n), Mazda, Xiaopeng (n), Aiways (n), Toyota, Honda, Lucid (n)	13.2 - 0.0	-	Laggards and Newcomers (n)

Source: CAM (2021).

2.1.2 Factor conditions

Factor conditions in Porter's Diamond refer to the natural, human and capital resources of a country. Skilled labour force or good infrastructure are examples of created factor conditions which, according to Porter, should be continuously developed. In this section, we will focus on the last two: the availability of labour and skills, and the availability of raw materials.

a. Labour

Although conventional and electric vehicles share some similarities, there are also significant differences between them. The main elements distinguishing BEVs from traditional vehicles are the use of **batteries** and **electric motors**. As a result, the electromobility market requires a different range of skills from workers compared to combustion engine vehicles. The main fields in which specialised skills are needed are as follows:

- **Research, development, and innovation**. Electric vehicles and batteries represent a new technological paradigm for cars. As such, they are demanding a significantly stronger innovation push compared to the highly consolidated ICE technology. More scientists are needed to conduct research to improve electric vehicle technology, such as chemists and material scientists to conduct research on batteries, recharging, and new materials;
- **Design and engineering**. Engineers are needed to improve and create new processes for manufacturing electric vehicles. Engineering technicians, software developers and industrial designers all contribute to design and software creation for e-cars. EVs are also increasing the need for technicians and engineers with electrical, mechatronic, and electrochemical skills;

- **Electric vehicle maintenance**. Electrical systems and the repair or installation of batteries require a specific skill set and specialised training.

  Simple mechanical repair has transformed into high-tech work, thus making computerised equipment and work with electronic components essential; and

- **Infrastructure development**. Urban and regional planners are needed to develop infrastructural upgrades, electrical power-line installers to conduct the wire work, and electricians to install charging stations.

The literature on the impact of the transition to electromobility on the overall demand for jobs and employment, however, is somewhat divided[60]. Recent studies have predicted significant job losses. For instance, a recent study by the Institute for Employment Research[61] predicts that almost 114,000 additional jobs will be lost by 2035 due to the electrification of powertrains. This translates to an addition of 10% to the unemployed population. In particular, the supplier industry is likely to be hit the hardest by the electromobility shift as labour requirements tend to be much higher in component manufacturing[62].

Conversely, the other side of research argues that despite job losses in fossil-fuel-focused industries in the shorter run, the long-term job creation of electromobility will neutralise the initial negative effect. A study by Boston Consulting Group (BCG) claims that there are only small differences between the amount of personnel needed to build an electric car and a conventional vehicle. BEVs might require fewer workers to be built but not the car as a whole because of additional steps in production, such as battery cell production and power electronics.[63] Meanwhile, several recent studies find that employment in the automotive sector is likely to be hit less hard than initially expected, and only a small number of jobs will be endangered[64, 65,66].

In section 2.1.4, we explore how electric car technology is expected to largely shift the set of suppliers acting in the value chain. Indeed, we have recently observed an increase in mass layoffs amongst some of the largest value chain players, including Daimler, Mahle, Continental and Bosch. The BCG study outlines two main reasons for this phenomenon: the lack of battery cell production and the time needed for reskilling[67]. Crucially, battery production in Europe is gaining momentum, and several factories are planning to produce battery cells in the coming decade (see below), translating to a

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60 An interesting overview of this discussion can be found here Clean Energy Wire, 2021, *How many car industry jobs are at risk from the shift to electric vehicles?*. Available at: https://www.cleanenergywire.org/factsheets/how-many-car-industry-jobs-are-risk-shift-electric-vehicles.

61 Mönnig, A. et al., 2019. *Electromobility 2035: Economic and labour market effects through the electrification of powertrains in passenger cars*. Institute for Employment Research. Available at: http://doku.iab.de/discussionpapers/2019/dp0819.pdf.

62 Herrmann, F. et al., 2020, *Auswirkungen von Elektromobilität und Digitalisierung auf die Qualität und Quantität der Beschäftigung bei Volkswagen*. Available at: http://publica.fraunhofer.de/eprints/urn_nbn_de_0011-n-6154803.Pdf.

63 Küpper, Daniel, et al, 2020, *Shifting Gears in Auto Manufacturing*.
Available at: https://web-assets.bcg.com/fd/de/20c24ec2407d9622175e45e84a2c/bcg-shifting-gears-in-auto-manufacturing-sep-2020.pdf.

64 Herrmann, F. et al., 2020, *Auswirkungen von Elektromobilität und Digitalisierung auf die Qualität und Quantität der Beschäftigung bei Volkswagen*. Available at: http://publica.fraunhofer.de/eprints/urn_nbn_de_0011-n-6154803.Pdf.

65 Dudenhöffer, F. 2021, *Car Study: Tightening of EU - CO2 Requirements and the effects on Jobs in the European Auto Industry*. Available at: https://www.car-future.com/media/center-automotive-research/CO2_Studie/CAR_Jobs_Study_EN.pdf.

66 Boston Consulting Group and Agora Verkehrswende, 2021, *Changing automotive work environment, Job effects in Germany until 2030*. Available at: https://www.agora-verkehrswende.de/fileadmin/Projekte/2021/BCG-Jobstudie/2021-07-01_E-mobility-Report_Results-Germany_EN.pdf

67 Mönnig, A. et al., 2019. Electromobility 2035: Economic and labour market effects through the electrification of powertrains in passenger cars.

potential of thousands of new jobs being generated in the value chain in parallel to the cuts made elsewhere.

b. Raw materials

Another major factor condition for electromobility is the availability of raw materials for batteries. The metals mainly used to produce these central components are lithium, nickel, and cobalt. Demand in those three raw materials is expected to dramatically increase in Europe by 2030[68]:

- **Lithium**: from 5kt in 2020 to 36kt in 2030;
- **Cobalt**: from 7kt in 2030 to 21kt in 2030;
- **Nickel**: from 26kt in 2025 to 276kt in 2030.

China is currently dominating in lithium, nickel, cobalt, quartz, and other rare earth elements supply. Specifically, lithium is primarily extracted in Australia and Chile and then refined in China. Although Europe also has some lithium resources, e.g. Serbia (Jadar deposit), Portugal, Spain, Finland, France (Massif Central), Austria and the Czech Republic, import dependence is still high.

On the one hand, the high import dependence of strategic and critical raw material (CRM) has a serious impact on the sustainability of the EU manufacturing industry, but on the other hand, the extent to which the EU could provide the mineral deposits is not clear and has yet to be sufficiently mapped. Simultaneously, importing the amount of raw materials that the coming European wave of EV-battery investment needs from the other side of the world is not an environmentally sustainable solution given the high CO_2 emission on account of transportation. The bottlenecks in the supply of lithium and China's dominance still leave European OEMs vulnerable to supply chain glitches with the risk of price spikes.

A study by Transport and Environment[69], however, argues that technological advancements will result in fewer raw materials needed for batteries over time. Moreover, Europe's dependency on imports for raw materials is expected to significantly decrease as over a fifth of lithium and nickel and 65% of cobalt needed to make a battery could come from recycling by 2035, depending on the competitiveness of recycled inputs, government regulations and the awareness of consumers.

2.1.3 Demand conditions

Despite the presence of factor conditions, the development of electromobility also depends on the level of demand for it. This section will outline both the factors driving the sector's growth and the factors hindering it.

a. Drivers for growth

Research suggests that drivers for growth come at different levels. On a governmental level, the motivation for support is driven by three different factors: environmental impact, energy security and economic benefits[70]. Besides the known environmental concerns, many governments consider EVs an opportunity to reduce their dependence on foreign oil supplies. At the same time, the transition to electromobility can offer a range of opportunities for sustainable innovation, growth, and employment,

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68 Transport & Environment, 2021, *From dirty oil to clean batteries*. Available at: https://www.transportenvironment.org/sites/te/files/publications/2021_02_Battery_raw_materials_report_final.pdf.

69 Ibid.

70 Serra, J. V. F., *Electric vehicles: technology, policy and commercial development*. Routledge, 2013. Available at: https://www.routledge.com/Electric-Vehicles-Technology-Policy-and-Commercial-Development/Serra/p/book/9781138374973 (payed wall).

both in manufacturing and the supply chain. As a result, countries are currently increasing incentives and are formulating policies to foster the BEV market and to ensure its competitiveness against conventional vehicles (e.g., favourable tax systems to BEV owners, preferential parking permits in dense urban centres or the right to drive in bus/taxi lanes)[71].

Incentives on the consumer level are somewhat different in nature. For instance, environmental consciousness is increasing among consumers, and it is one of the most prominent factors when deciding to purchase a BEV. Moreover, ownership benefits provided by the government also play a role in driving the decision for an electric vehicle. Research shows that BEVs are currently the cheapest option in terms of total ownership cost (TOC) over vehicles' lifetime for medium-sized cars, standing at EUR 75,000[72]. Other elements that are taken into consideration by consumers include:

- BEVs have lower noise levels than petrol and diesel vehicles;
- maintenance costs are much lower for electric vehicles;
- electric cars offer a cheaper mobility solution given the increasing fuel prices;
- electric motors can operate unproblematically at much higher speeds than internal combustion engines; and
- electric vehicles can be "refuelled" at the comfort of one's own home.

b. Barriers to adoption

On the other hand, the electromobility market's development also faces several barriers, including social, technical, economic, psychological, and cultural issues[73,74,75].

First and foremost, in the socio-technical list comes the availability of charging infrastructure, as it is a major issue in BEV adoption. Infrastructure currently varies between the EU Member States; for instance, the Netherlands counts over 32,000 recharging points and over 119,000 registered EVs compared to Greece, which has less than 40 recharging points and just over 300 EVs[76]. Linked to this, consumers' perception that BEVs cannot cover the desired distance without a recharge and concerns about battery performance act as further obstacles to demand[77].

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71 Berkeley, N.,, Bailey, D., Jones, A., and Jarvis, D., 2017, *Assessing the transition towards Battery Electric Vehicles: A Multi-Level Perspective on drivers of, and barriers to, take up*. Transportation Research part A: policy and practice 106 (2017): 320-332. Available at: https://ideas.repec.org/a/eee/transa/v106y2017icp320-332.html.

72 Peplow L. and Eardley C., 2021, *Electric Cars: Calculating the TCO for Consumers*, BEUC. Available at: https://www.beuc.eu/publications/beuc-x-2021-039_electric_cars_calculating_the_total_cost_of_ownership_for_consumers.pdf.

73 Ibid.

74 Browne, D. et al., 2012. How should barriers to alternative fuels and vehicles be classified and potential policies to promote innovative technologies be evaluated?, Journal of Cleaner Production, 35, 2012, 140 – 151. Available at: http://www.tara.tcd.ie/handle/2262/76245.

75 Egbue, O. et al., 2012. *Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions*, Cogent Engineering. Available at: https://www.tandfonline.com/doi/full/10.1080/23311916.2020.1796198.

76 Niestadt, M. et al., 2019. *Electric road vehicles in the European Union: Trends, impacts and policies*, European Parliament Think Tank.
Available at: https://www.europarl.europa.eu/thinktank/en/document.html?reference=EPRS_BRI%282019%29637895.

77 Berkeley, N, et al., 2017. *Assessing the transition towards Battery Electric Vehicles: A Multi-Level Perspective on drivers of, and barriers to, take up,* Transportation Research Part A: Policy and Practice, Elsevier, vol. 106(C), pages 320-332. Available at: https://ideas.repec.org/a/eee/transa/v106y2017icp320-332.html.

Moreover, investment in BEV technology was for a long time limited by OEMs. On the one hand, this was a result of manufacturers' previous investment activity.

Prior to the advancement of electromobility, manufacturers heavily invested in "cleaner" solutions to improve ICE vehicles, such as stop-start systems.

As a result, most of the sunk costs presently faced by OEMs are related to ICE technologies, which makes some manufacturers somewhat reluctant to switch investments to disruptive BEV technologies[78].

Some resistance towards EVs relates to the fact that carmakers have generally not been able to make profits from their sales, especially in the case of BEVs[79]. Despite government incentives, EVs, and especially BEVs, still have a significantly higher final price compared to similar ICE cars, and consumers' willingness to pay a premium for electric cars is still limited. Notwithstanding the accelerated fall in the price of batteries in recent years, BEVs are unlikely to reach price parity with ICE technology in the mid-segment of the market before 2025[80] [81]. This fact explains the industry's strategy of suppressing EVs until the limit of the entry into force of the new regulatory standards for 2020/2021.

Finally, economic and attitudinal factors hindering the transition to electromobility on the consumer side include:

- The uncertainty about the payback period of a BEV;
- the lack of variety in models and styles in the BEV market compared to conventional vehicles;
- the scepticism that still exists among consumers regarding the actual environmental performance of electric vehicles; and
- the generally limited consumer awareness regarding costs and benefits, and efficiencies.

It is important to highlight that consumers' attitudes are improving fast. A recent study by Ofgem indicates that one in four consumers plan to purchase an EV or a plug-in hybrid in the next five years[82]. A recent Consumers Reports' survey also indicates that 71% of US drivers would consider buying an electric car in the future, while almost a third of them considered an EV as their next vehicle purchase[83].

2.1.4 Related and supporting industries

Batteries are the main single cost component of BEVs, representing around 40% of their manufacturing cost in 2020[84]. The still relatively high cost of batteries is mainly responsible for BEVs

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78 Ibid.

79 McKinsey, 2019,*Making electric vehicles profitable McKinsey Center for Future Mobility Making electric vehicles profitable*. Available at: https://www.mckinsey.com/~/media/McKinsey/Industries/Automotive and Assembly/Our Insights/Making electric vehicles profitable/Making-electric-vehicles-profitable.pdf.

80 Ibid.

81 Transport & Environment, 2019, *Electric surge: Carmakers' electric car plans across Europe 2019-2025*. Available at: https://www.transportenvironment.org/publications/electric-surge-carmakers-electric-car-plans-across-europe-2019-2025.

82 Ofgem, 2021, *One in four consumers plan to buy an electric car in next five years according to Ofgem research*. Available at: https://www.ofgem.gov.uk/publications/one-four-consumers-plan-buy-electric-car-next-five-years-according-ofgem-research.

83 Consumer Reports, 2020, *Electric Vehicles and Fuel Economy: A Nationally Representative Multi-Mode Survey*. Available at: https://article.images.consumerreports.org/prod/content/dam/surveys/Consumer Reports Electric Vehicles Fuel Economy National August 2020.

84 Ruffo, G. H., 2020, *EVs are Still 45% More Expensive To Make Than Combustion-Engined* Cars. Available at: https://insideevs.com/news/444542/evs-45-percent-more-expensive-make-ice/.

being significantly more expensive than similar ICE vehicles, which means innovations in battery design and production will be a determining factor in the overall development of the sector.

The fact that, at the time of this study, none of the global top ten EV lithium-ion (Li-ion) battery producers is European means in and of itself that the EU manufacturers are over-exposed to problems within the battery global value chain[85]. In 2021, China dominates the EV battery global capacity accounting for 77% of the total, and the top producing firms are from Asia[86].

However, S&P Global expects geographic diversification to accelerate as more countries become Li-ion battery producers given the preference to manufacture close to the markets due to weight and the cost of shipment. The EC's European Battery Alliance[87], established in 2017, also appears to be offering tangible results in the form of investments in manufacturing capacity and industry consortia. The establishment of battery production in Europe is essential to fill an important gap in electric vehicles value chains, anchoring a very large part of the value-added and jobs generated by the EV industry. **Based on current investment announcements, the European production capacity is expected to be enough to satisfy the region's needs until 2030**, escalating to 20-25% of the world's supply by 2030[88].

Table 2.2: Rapid pace of EV Li-ion battery Investment in Europe 2020 / 2021

Company	Capacity (GWh)	Status	Country
MES	15	In operation	Czech Republic
Samsung	30	In operation	Hungary
SK Innovation	18	In operation	Hungary
Northvolt Labs	0.5	In operation	Sweden
Envision AESC	1.9	In operation	United Kingdom
Microvost	1.5	Under construction	Germany
Northvolt Zwei	20	Under construction	Germany
SVOLT	22	Under construction	Germany
Tesla	40	Under construction	Germany
Italvolt	70	Under construction	Italy
LG Chem	64	Under construction	Poland
Inobat	10	Under construction	Slovakia
Northvolt	ETT 40	Under construction	Sweden
ACC	24	Planned	France
ACC	16	Planned	Germany

85 For example, one of the experts consulted for this study reported an instance wherein a major European OEM received outdated technology compared to Asian competitors from the home country of the battery manufacturer.

86 S&P Global Market Intelligence, 2021, *Top electric vehicle markets dominate lithium-ion capacity growth*. Available at: https://www.spglobal.com/marketintelligence/en/news-insights/blog/top-electric-vehicle-markets-dominate-lithium-ion-battery-capacity-growth.

87 European Commission, 2021, *European Battery Alliance. Available* at: https://ec.europa.eu/growth/industry/policy/european-battery-alliance_en.

88 Fitch Solutions, 2021, Batteries Investment Round Up: New Players and Countries Begin to Make Their Mark. Available at: https://www.fitchsolutions.com/autos/mid-year-update-autos-key-themes-2021-06-07-2021.

Company	Capacity (GWh)	Status	Country
Varta	Pilot Plant	Planned	Germany
SK Innovation	30	Planned	Hungary
Verkor	16	Announced	France
BMW	Pilot Plant	Announced	Germany
CATL	70	Announced	Germany
Cellforce	1	Announced	Germany
Farasis	15	Announced	Germany
Leclanche	1	Announced	Germany
GS YUASA	Na	Announced	Hungary
FAAM/Lithops	0.2	Announced	Italy
FREYR	43	Announced	Norway
Morrow	32	Announced	Norway
Panasonic	Na	Announced	Norway
AMTE	20	Announced	United Kingdom
Britishvolt	30	Announced	United Kingdom

Source: Fitch Solutions (2021)[89].

There is also an emergence of European initiatives, despite current investment plans pointing that Asian firms will be responsible for a large part of the local supply. Having European battery manufacturers will be important to leverage the local research and development capacity in battery-cell production and design, recycling, and materials, as well as fostering innovation ecosystems and co-development possibilities in the value chain. It should also leverage the European industry's role in the transition to the new technologies expected to replace the current Li-ion dominance in the long term, such as solid-state lithium-metal batteries. Northvolt is the most ambitious, advanced, and strategic European battery project, relying on investments and supply agreements with VW, BMW and Volvo and aiming for 25% of the European market. VW, Stellantis and Renault have all announced plans to develop their own independent battery production capabilities in-house or through joint ventures, with pilot or full-scale plants predicted[90, 91, 92].

Recently, emphasis has been increasing on ensuring that battery recycling capacity exists to secure Europe's position as a leader in the circular economy and to build a strong position in an industry wherein scale will be fundamental. Recycling will also be central to diversify the sources of raw materials and create resilience in the value chain. Northvolt has indicated ambitious goals for recycling, and the European Battery Alliance has registered new pilot plant investments addressing what it

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[89] Fitch Solutions, 2021. *Batteries Investment Round Up: New Players and Countries Begin to Make Their Mark*. Available at: https://www.fitchsolutions.com/autos/mid-year-update-autos-key-themes-2021-06-07-2021.

[90] Financial Times, year, title (cursive). Available at: https://www.ft.com/content/6be4159e-cdb7-48e1-b0d1-4b88054805f9.

[91] Groupe PSA and Fiat Chrysler Automobiles, 2021, *First Half 2021 Results*. Available at: https://www.groupe-psa.com/en/newsroom/corporate-en/groupe-psa-and-total-create-automotive-cells-company/.

[92] Patel, T., and Connan, C., 2021, *Renault CEO Sees Revamp Paying Off Amid Virus, Chip Crunch*, Bloomberg. Available at: https://www.bloomberg.com/news/articles/2021-06-30/renault-pledges-to-lower-battery-costs-in-electric-car-push.

considers 'one of the remaining challenges' for the European battery industry[93] [94]. Although encouraging, one must observe that these developments are 2-3 years behind China's selection of 17 cities to begin piloting EV-battery recycling in 2018.

Battery manufacturing equipment is an important component of the value chain that tends to receive less attention. The European position in industrial machinery has been traditionally strong, but this has not been reflected in battery manufacturing thus far. According to a source interviewed for this work, most of the equipment for cell production of European plants is being imported from China and Korea, where battery production for electronics is long present. This account is compatible with reports found in the specialized media[95]. This picture is especially critical because there is a race to invest in battery production now and, therefore, limited time to foster new players in the equipment subsector.

2.1.5 Other components

Electric cars are simpler to assemble than combustion engine vehicles. An ICE powertrain has around 12,000 components versus a few hundred in BEVs. These components are also, in general, simpler to manufacture than the elaborate machining and casting techniques necessary to produce ICE parts. Studies indicate that, if excluded the production of battery cells, the total number of workhours needed for *components* is 15%-30% lower for BEVs[96][97].

In fact, about 31% of the content per vehicle of ICEs, related mostly to the engine and transmission, is completely eliminated in BEVs and replaced with electric motors, battery packs and power electronics[98]. This shift means the set of suppliers that will be demanded by the automotive industry in the future will also completely change. The powertrain components will shift from the mechanical engine and transmission systems, such as gearbox, exhaust pipes and injectors, to mechatronic and electrical systems like e-motor, converters, inverters, and high-voltage wiring. The timing of this transition will largely depend on (i) the adoption of electric vehicles, (ii) the mix between PHEVs and BEVs, since the former still contain ICE mechanical systems, and (iii) the extent to which OEMs will decide to internalize component manufacturing[99].

Nonetheless, large changes can be expected in the value creation structure of automotive supply chains, with many traditional first-tier suppliers downsizing and losing ground to new firms specialized in power electronics or more successful in transitioning to the high growth segments.

2.2 Other aspects of the Green Transition

2.2.1 Li-ion vs Hydrogen Fuel Cells: an Environmental Sustainability Matrix

Views are polarized not only within academia but across the OEMs themselves. VW has already articulated that Li-ion batteries are the winner while Honda, Hyundai and Toyota remain staunch advocates of hydrogen fuel cells (HFCs).

93 Northvolt, 2019, *Northvolt launches recycling program targeting 50 percent recycled material in new cells*. Available at: https://northvolt.com/articles/announcing-revolt/.

94 EIT Inno energy, 2021, *New Battery recycling initiatives in Europe*. Available at: https://www.eba250.com/new-battery-recycling-initiatives-in-europe/.

95 For example, http://www.thelec.net/news/articleView.html?idxno=880 and https://rechargebatteries.org/wp-content/uploads/2020/01/RECHARGE-Position-Paper_Industrial-Investment_December-2019.pdf.

96 Herrmann, F. et al., 2020, *Auswirkungen von Elektromobilität und Digitalisierung auf die Qualität und Quantität der Beschäftigung bei Volkswagen*. Available at: http://publica.fraunhofer.de/eprints/urn_nbn_de_0011-n-6154803.Pdf.

97 Küpper, D, et al, 2020. *Shifting Gears in Auto Manufacturing*.

98 Ibid.

99 Mckinsey, 2019, *Reboost: A comprehensive view on the changing powertrain component market and how suppliers can succeed.*

At the time of this study, Li-ion, based on the unprecedented wave of investment in battery manufacturing plants across Europe, is by far the favoured option from an OEM perspective.

Still, there is no outright winner, and essentially the two technologies are likely needed to help significantly lower CO_2 emissions to profoundly enhance the 'greening' of the sector. Based on multiple sources and our interviews, we developed a matrix (Table 2.3) outlining the pros and cons of the two technologies.

In summary, when it comes to the case for Li-ion batteries and hydrogen fuel cells, it should not be a case of either-or. While both currently fail the 'greening' litmus test in terms of pollution when they are made and transported, they are also both a major contributor to sustaining the environment when in ultimate use. Li-ion will continue to be optional for shorter repetitive journeys while longer-haul and greater power requirements will increasingly tip the balance in favour of HFC. While technology, infrastructure, and the environment all matter, shaping perceptions and confidence around electromobility is equally important. We believe that, when the full potential for 'green' HFCs is unlocked and when consumers witness investment in HFC infrastructure, the efficiencies, accessibility, and differences between the two sources might become marginalized to the point that it will be the overall supply chain with the lowest carbon footprint that will become a major consumer differentiator**. Green hydrogen (zero-carbon hydrogen) is still by far the most expensive hydrogen to produce, but as its cost falls in the coming years, the case for HFCs will strengthen over the next decade**. Consequently, it is in the EU's best interest to further enable the innovation and greening of the two power sources.

Table 2.3: Li-ion vs HFCs environmental sustainability matrix

Li-ion Battery EVs		Hydrogen Fuel Cell EVs	
Technological and Efficiency Perspective			
Positive Attributes	**Concerns Cited**	**Positive Attributes**	**Concerns Cited**
1. As clean as HFC and as of 2021 is cheaper, easier, and safer to handle. 2. BEVs have an efficiency of 70% to 80% - meaning that around three-quarters of the electricity generated by the grid is actually applied to propulsion. 3. Currently the most commercially viable from a European OEM perspective. 4. OEMs and battery manufacturers are making good	1. Less energy-dense, slower to recharge and creates more 'range anxiety' than HFC. 2. Mining for crucial metals like cobalt, lithium, and nickel is raising environmental concerns. 3. Safety concerns increasing due to 'thermal runaway' - fire risk and decision by the US National Highway Traffic Safety Administration (Aug 16 2021) to investigate Tesla's autopilot system over crashes.	1. Old but proven technology (created in 1839 by Sir William Grove). 2. Electricity, heat and (potable) water outputs with hydrogen (the most common element in the universe) and oxygen (which is abundant) as inputs. 3. Energy to weight ratio circa ten times greater than Li-ion batteries - thus, offers much greater range while being lighter and occupying smaller volumes. 4. Quick refuelling times.	1. If the electricity used for hydrogen extraction is not from a renewable energy source, this propulsion can be 'dirtier' than a typical gasoline car. 2. Only about 25% to 35% of energy actually makes it to the wheels of an HFC car. 3. Storing hydrogen as a gas is expensive and energy-intensive. 4. Highly inflammable - tends to escape containment and reacts with metals rendering them more brittle and prone to breakage.

<table>
<tr><th colspan="2">Li-ion Battery EVs</th><th colspan="2">Hydrogen Fuel Cell EVs</th></tr>
<tr>
<td>progress towards improving battery efficiencies and bringing prices to below $100 per kilowatt-hour (kWh) - a rate at which EVs can compete with traditional ICE vehicles.</td>
<td>4. Lack of charging infrastructure and inconvenience for those with no home charging facility.
5. Risks of bottlenecks in the battery supply chain, which can disrupt production and spike prices for lithium and related minerals and materials.</td>
<td>5. No harmful emissions from the vehicle - only water.
6. With Airbus aiming to have its three concept hydrogen aircraft in operation by 2035, this will boost consumer and investor confidence in HFCs.</td>
<td>5. Starting and restarting in temperatures below freezing point can be problematic.
6. Lack of HFC refuelling locations.</td>
</tr>
<tr><th colspan="4">Possibilities of large-scale, environmental-friendly and competitive production</th></tr>
<tr>
<td colspan="2">• Lithium is mined from different sources, including brine, clay, and rock - it can take 2.2 million litres of water to mine every tonne of lithium.
• Concerns about worker and environmental safety (especially in Africa and the Democratic Republic of the Congo in particular - accounting for circa 70% of the cobalt used in Li-ion batteries).
• Around one-third of the world's lithium comes from salt flats in Chile and Argentina, where the material is mined using huge quantities of water in otherwise arid areas.
• Battery grade lithium can also be produced by exposing the material to very high temperatures - a process used in China and Australia - which consumes large quantities of energy.
• 90% of the world's trade travels by sea, which generates 3% of the world's greenhouse gasses and thus, neither is the mining nor the shipping of cobalt/quartz / Li-ion 'green'.</td>
<td colspan="2">• Hydrogen is only as 'green' as the method for production.
• Currently (Q3/Q4 2021), circa 95% of hydrogen is produced from fossil fuels via steam reformation.
• A steep change in renewable energy growth is underway, with renewables set to provide around 30% of global power demand by 2023 - RE will thus improve the environmental credentials of both Li-ion and HFC systems.
• According to IRENA, in the long-term, creating hydrogen fuel via water electrolysis has the potential to become 40 to 80% cheaper.
• New systems of electrolysis will eliminate the need for rare elements like platinum and iridium</td>
</tr>
<tr><th colspan="4">Supply chain resilience dynamics</th></tr>
<tr>
<td colspan="4">• With the United Nations still maintaining a peacekeeping presence in the DRC where global quartz production is concentrated, the probability of supply chain disruption is high.
• Although merely an investor in many cobalt mines, China controls 70% of the capacity to convert cobalt ore into cobalt chemicals for the battery industry, representing considerable control of the supply chain.
• While Australia alone boasts five of the ten biggest lithium deposits in the world, over 60% of lithium processing occurs in China.</td>
</tr>
<tr><th colspan="4">Closing observations</th></tr>
</table>

Li-ion Battery EVs	Hydrogen Fuel Cell EVs

- The main observation is that the two technologies must be pursued with alacrity to contribute to a sustainable environmental solution.
- At the start of this decade, Li-ion BEVs are in the clear lead, fuelled by the exceptional successes of Tesla globally and the successes of most European OEMs are achieving in terms of meeting their own individual emissions targets aligned with the EU target of 95g/CO2/km.
- While many analysts are predicting that the Li-ion / HFC car sales ratio will essentially remain over the future decade in favour of the former, this gap may well narrow on account of the following:
  a) Even with the increased investment in lithium-ion battery manufacturing plants within the EU, the supply chain is far more dependent on global trade than HFC production. Furthermore, as consumers become better informed and as consumer preferences become more influenced by the entire greenhouse gas footprint from sourcing and manufacturing (i.e. not just the use of it), there will be an increasing awareness that making lithium-ion batteries is an energy-intensive manufacturing process while transportation which can routinely involve shipping lithium from Chile to China to Japan or South Korea in and of itself creates a significant CO_2 footprint on top of which is the shipping to the EU for the inputs for battery production.
  b) The dramatic increase in using renewable energy combined with major HFC technological and innovation spill-overs from the aviation sector probably explains why so many automotive executives (62% - KPMG study 2017) believe that hydrogen offers the true breakthrough for electromobility and will overtake lithium-ion related propulsion. Nonetheless, based on 2016 and 2017 analysis by the Copenhagen Centre on Energy Efficiency, compared to BEVs, HFC vehicles energy losses were considerable in terms of electrolysis, storage/distribution, and especially the H_2 to electricity conversion manifesting in an overall efficiency rating of only 23% for HFC vs 76% for BEVs.
- Both lithium-ion batteries and HFCs do not pollute when they are being used in EVs, but both pollute when made and transported. A study by Circular Energy Storage reported that 'if an electric vehicle is using a 40 kWh battery, its embedded emissions from manufacturing alone would be the equivalent to the CO2 emissions caused by driving a diesel car with fuel consumption of 5 litres per 100 km in between 11,800 km and 89,400 km before the electric car has even driven one metre. At the higher range, an electric car would first have a positive climate impact only after seven years for the average European driver.
- In terms of HFC contributing to green mobility in the future, McKinsey Vienna opined that most large OEMs have teamed up to work on the technology with associated systems development. For commercial vehicles, McKinsey models show that fuel-cell EVs can break even with BEVs within the next five years and will also achieve a lower total cost of ownership than diesel by 2030.

Sources: FURO Systems (2021) Lithium-ion Batteries vs Hydrogen Fuel Cells in Electric Vehicles.
Green Car Reports. (2020). Battery-electric or hydrogen fuel cell? VW lays out why one is the winner.
AMS Composites. (2020). Hydrogen Fuel Cell vs Lithium-ion - The Future of Transports.
Nature. (2021). Lithium-ion Batteries need to be greener and more ethical.
Holmefjord, K. (2021). The Engineers: Clean Energy: BBC World / Corvus Energy (Norway).
Melin, H. (2019). Analysis of the climate impact of lithium-ion batteries and how to measure it: Circular Energy Storage.
Tsakiris. A. (2019) Analysis of hydrogen fuel cell and battery efficiency: Copenhagen Center on Energy Efficiency.
Fitch Solutions. (2021) Batteries Investment Round Up: New Players and Countries Begin to Make Their Mark.
McKinsey & Company. (2020) McKinsey Electric Vehicle Index: Europe cushions a global plunge in EV sales.
Energy Sector Management Assistance Program. (2018). Electric Mobility and Development - an Engagement Paper from the World Bank and the International Association of Public Transport.
IRENA. (2020). Green Hydrogen Cost Reduction: scaling up electrolysers to meet the 1.5 C climate goal.

2.2.2 Challenges and opportunities related to power grid integration

As the number of EVs continues to rise, challenges for the grid are likely to arise**. Nonetheless, the increased adoption of EVs is unlikely to cause a significant increase in the overall power demand.** McKinsey estimates that a 40% EV penetration in the total car fleet in Germany would cause only around a 6% increase in the total power demand[100]. In the short to medium term, the challenges to the grid should revolve around the load curve. EVs are expected to cause a surge in the evening peak load, as most people will charge their cars when returning home from work. This increase in peak loads should be more meaningful for grids that are particularly constrained by transmission and distribution infrastructure[101]. The more substantial challenge, however, will be in the combination of peak load times with the geographical spread of EVs, which will be inevitably uneven in space. Locations with a high concentration of EVs or supercharging stations will be prone to push local substations beyond capacity and, if left unmanaged, demand costly investments from grid operators.

2.2.3 V1G (Smart Charging) & V2G (Vehicle to Grid) solutions and opportunities

Besides possible negative effects on peak loads, EVs energy storage capacity also offer opportunities to increase the flexibility and efficiency of the grid in the context of increasing energy generation by unpredictable renewable sources (solar and wind). To manage high peak loads difficulties and, at the same time, leverage the potential synergies, it will be vital to create a 'smart grid' that has smart charging and vehicle-to-grid technology integration. V1G technology (or smart charging) enables controlling the timing and magnitude of charging power from the power source to the EV. The technology can be used for congestion management, frequency control (including peak-shaving) and charging from renewables. V1G technology can also be useful to deploy when power demand is too high, i.e. charging power levels could be decreased or delayed at peak times to reduce the burden on the grid, which is an obvious solution to the evening peak load demand.

V2G technology (vehicle-to-grid) goes one step further. This technology allows power from the batteries of EVs to be fed back into the grid. Not only the timing and magnitude of charging can be altered but also the direction. The same technology can also be used to power car owners' homes (V2H), buildings (V2B) and more. V2G allows for a range of useful applications:

- Frequency regulation: currently, Germany alone wastes wind energy estimated to be equivalent to 1% of its consumption due to absent storage capacity during peak generation times[102]. EVs can charge when solar and wind energy provide more energy supply. When there is a shortage of energy supply, the EVs can feed some energy back into the grid to satisfy the high demand. In essence, in the absence of storage options geographically close to generation points that avoid transmission losses, all the EVs connected to the grid could be used as storage facilities for excess energy supply that can then be put to good use at a later moment;

[100] McKinsey, 2018. The potential impact of electric vehicles on global energy systems. Available at: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-potential-impact-of-electric-vehicles-on-global-energy-systems.
[101] Proctor, D., 2020, *Driving Change on the Grid – the impact of EV adoption,* POWERMAG. Available at: https://www.powermag.com/driving-change-on-the-grid-the-impact-of-ev-adoption/.
[102] Menzel, S., 2021, *Bidirektionales laden: so will Volkswagen am Speichern von Strom verdienen*, Handelsblatt. Available at: https://www.handelsblatt.com/mobilitaet/elektromobilitaet/elektromobilitaet-bidirektionales-laden-so-will-volkswagen-am-speichern-von-strom-verdienen/27052182.html.

- Peak-shaving: using V2G can reduce peak usage levels. This can be useful both at the macro (whole areas) and micro (organizations, households etc.) levels, for instance, in saving on households' energy costs;
- Arbitrage: allows EV users to charge during off-peak hours and sell power back to the grid at peak hours; and
- Energy reserve: EVs can serve as an emergency energy reserve during power outages.

McKinsey estimates that 'ancillary services', including automating EV-charging patterns to optimally deliver V2G services and minimize peak demand charges, could be worth USD 15 billion in revenues and cost savings in the US alone in 2030[103]. In this context, the VW Group announced plans to implement bi-directional capabilities in the second generation of its basic BEV platform, to come to the market already in 2022. In parallel, they are exploring business models that monetize the storage capacity of BEVs by making them available to utility companies and grid operators.

Despite the variety of potential business models that can be explored, important challenges remain.

The need for standardization and communication between all the different actors involved in EV production and energy distribution is an important hurdle to realizing the potential of V2G technology. Co-operation between regulators, grid operators and carmakers will be required to make this system operational. Currently, neither the grid, charging stations nor EVs coming to market are equipped to deal with V2G functionalities.

2.3 Conclusions and SWOT assessment

To conclude this chapter, we perform a strengths, weaknesses, opportunities, and threats (SWOT) analysis of this upcoming industry and systematically take stock of the main forces acting upon the European transition to electromobility. Figure 2.3 depicts the main strengths, opportunities, weaknesses, and threats to the sector envisioned by our analysis.

We consider the **main strength of Europe to lie in its vigorous established automotive sector**. Europe concentrates a large part of the leading international carmakers in sales volume, quality, brand, and technology, with a wide footprint in world markets. The bloc is also home to a highly competitive regional value chain and deeply developed supply base. This sectoral base has been valuable to leverage the know-how, resources, technology, and innovation capacity necessary for the transition to electric vehicles.

Other strengths are the size of the integrated regional market, the quality and coherence of the sector regulation at the European level, both of which are instrumental in leveraging relevant strategic decisions from the sector players that less important markets and respective regulators would be unable to provoke. This is most evident in the recent emergence of battery production in the continent. Another strength is the leading innovation ecosystem, with world-class research centres, universities, and training institutions.

One of the main weaknesses of the electromobility ecosystem in Europe is the absence of a dynamic start-up scene amongst carmakers, such as the ones observed in the US and China. Besides Tesla, which remains the sector leader, other newcomers like Lucid and Nio are providing a remarkable

[103] McKinsey, 2020, *Charging Electric-Vehicle Fleets: How To Seize The Emerging Opportunity.* Available At https://Www.Mckinsey.Com/Business-Functions/Sustainability/Our-Insights/Charging-Electric-Vehicle-Fleets-How-To-Seize-Theemerging-Opportunity.

challenge to the incumbents in the car sector. A different picture is seen in battery production, where European start-ups are leading the local presence.

Based on the European Start-up Prize for Mobility (2020), the mobility segment represents an entrepreneurial impetus that is gaining momentum showcased, for example, by French start-up Electra successfully raising €15 million to establish a network of ultra-fast charging stations. The core question for European Parliament members is not so much is this momentum sustainable but, rather, is the pace of momentum sufficient to safeguard a technological lead vis-à-vis competing regions for automotive design and development.

The answer to this question will become clearer over the next three years, but already several sources, including Bird and Bird,[104] are cautioning that Germany 'seems too slow when it comes to e-mobility.' If, for example, the number of semiconductor start-up companies served as a barometer to gauge innovation momentum, with China registering over 22,000 new semiconductor companies in 2020 and a further 4,350 over the first two months of 2021[105], **Europe is already in the 'catch-up' mode.**

Another weakness comes as a side-effect of the European regulatory framework, which has caused a relatively larger market presence of PHEVs in Europe. The innovative and productive performance of European OEMs is still weaker compared to many international competitors in purely electric cars. In that sense, it is not surprising that, despite the strong presence in traditional vehicles, European carmakers have still struggled to enter the Chinese BEV market, the largest in the world.

Regarding opportunities, the presence of European carmakers and suppliers in international markets, including the high-growth Chinese market, provide an important growth platform that is unavailable to many competitors. Despite some small recent gains, Chinese BEV carmakers, in particular, do not have a significant direct presence in the European or international markets, with the exception of Geely through Volvo. Other opportunities relate to the leading role Europe is taking in sustainability and decarbonisation, which will keep the industry high in the list of policy priorities for regulators and member-states, and at the forefront of sustainability-related technological developments.

Finally, the **main threat to the development of electromobility in Europe is still the weak battery supply base**, in which Asian producers have a clear head start and are already establishing a presence in Europe. This process might weaken the European value generation and innovation capacity in a key subsector. In any case, a strong dependence on foreign producers of raw materials is expected, which are frequently produced following unsatisfactory environmental and social standards. Other threats come from internal regional inequalities in Europe, which are being perpetuated by the upcoming industry, as investments, EV sales and the expansion of the charging infrastructure concentrate in traditional centres; and the mismatch between the skills provided by the education system, focused on the ICE paradigm, and the skills demanded by the electromobility industry.

[104] Bird and Bird. (2019) *Who's next? Selling off German technologies in the electromobility sector,* Available at: https://www.twobirds.com/~/media/pdfs/germany/2019_01_english-article_ausverkauf-deutscher-technologien-in-der-elektromobilbranchetranslationinv.pdf?la=en&hash=8DF9D316678161E8041A0C0BD9CAC73CB95F0138.

[105] Protocol. (2021) *Chinese companies are making their own semiconductors - based on research by Qichacha,* Available at: https://www.protocol.com/china/chinese-companies-make-own-semiconductors#:~:text=Appliance%20makers%20TCL%2C%20Konka%20and,two%20decades%20before%20U.S.%20sanctions.

Figure 2.3: SWOT Analysis of Electromobility in Europe

Strengths

- Established carmakers and supplier base with strong brand value, technological and financial capacities
- Large and integrated continental consumption market
- Clear and coherent long-term policy framework at the European level
- Highly qualified labor force, leading ecosystem of R&D and training institutions

Weaknesses

- High dependence on established firms, with no relevant newcomers amongst carmakers
- Relatively high dependence on plug-in hybrids and weaker performance in fully electric vehicles sales and innovation
- Unequal infrastructure development between Member States as well as regions and cities
- Low penetration in the Chinese BEV market

Opportunities

- Established presence in international markets, including the high-growth Chinese market
- Ambitious sustainability goals and regulations by the EC and member-states,
- Strong incentives for market growth coming from the EU and lead member-states
- High engagement and priority to the sector in the European industrial strategy

Threats

- Unestablished battery supply base, strong presence, and tradition of Asian firms in battery production
- Dependence on foreign supply of raw materials for battery cell production
- Technological competition from US and Asian OEMs and newcomers
- Regional inequality in terms of production, infrastructure and EV uptake
- Possible mismatch between skills being offered to the established markets and demand from the upcoming electric car sector

3 DIGITALISATION OF THE EU AUTOMOTIVE SECTOR

KEY FINDINGS

- The automotive sector is moving from a hardware to a software orientation, increasing the importance of digital products and services.
- Dual challenge from both new entrants such as digital and technology companies moving into the sector as well as Chinese OEMs strongly improving their innovative capabilities.
- The EU automotive sector is well placed in terms of innovation in future technologies in connectivity, software architecture and autonomous driving; however, many strategic competencies lie with large US and Chinese technology companies.
- While EU automotive companies are leading in terms of R&D intensity, the EU is lagging in ICT R&D, which combined with the increasing importance of ICT for the sector, has led to the EU automotive sector leadership position shrinking.
- The existing lack of skilled labour in technical skills in software engineering and other digital skills is likely to intensify with advancing digital transition.
- The current semiconductor shortage is slowing production and development of vehicles; however, huge investment into the EU electronics industry could address this issue and lead to future overcapacities.
- Supporting infrastructure for widespread deployment in terms of 5G technology is progressing throughout most of Europe; however, uncertainties about the use of technologies from Huawei could slow deployment.
- New mobility concepts and shared services will impact future mobility and thereby likely reduce vehicle demand.

3.1 Connectivity and autonomous vehicles

Shaping Europe's digital future has been identified as a key priority for the EU. For the automotive sector, this is highlighted in the move from a hardware-oriented sector to one increasingly driven by software and (digital) services. Specifically, connectivity is seen as an enabler for other services and technologies, which will drive innovation in the sector[106]. This shift is exemplified by an intensification of innovation in the fields of digital and Information and Communications Technology (ICT) technologies. In 2010, about 26% of innovations at OEMS were in the areas of connectivity, Advanced Driver Assistance Systems (ADAS) and interfaces. In 2020, this number reached 55%[107]. The increasing importance of technologies such as parking assistants, interfaces, software services, voice control, and augmented reality, therefore, calls for an assessment of the readiness of the EU automotive sector to innovate in these areas.

[106] Bratzel, S.; Tellermann, R.: CCI 2021 – Connected Car Innovation Studie. Center of Automotive Management, Bergisch Gladbach.

[107] Based on the CAM database on innovation trends among 30 OEMs and a selection of start-ups, which identified 333 connectivity relevant innovations.

Following Porter's diamond model, we first look at the strategic positioning of the EU industry and examine the impact of new entrants. We then assess factor conditions such as innovation, investment, and skills, before discussing expectations on how demand in the EU will develop. Finally, we address the importance of supporting industries and the potential risks of dependencies.

3.1.1 Firm strategy, structure and rivalry

a. The race towards connected and autonomous vehicles

The importance of software and digitalisation has been growing exponentially for OEMs since the introduction of automotive software in the 1970s. Recently, this has accumulated into a potential disruption of the structure of the industry. It is expected that manufacturers and suppliers will have to increase investments while dealing with sinking margins from their core business and increasing competition from new entrants. In particular, traditional automotive manufacturers will need to consider investing in new mobility services, software development and production capacity for the hardware required in future automobiles[108].

Four main trends in automotive software technology are reshaping the industry[109]:

- **Computer architecture centralisation** to reduce complexity and integrate functions in fewer and standardised Electronic Control Units[110] that reduce the probability of malfunctions and maintenance costs;
- **Standardised communication** for in-vehicle communication (through ethernet) to increase cost-efficiency, communication speed, and reduce weight;
- **Connectivity and cooperation** in allowing vehicles to communicate between each other and with the infrastructure; and
- **Autonomous functions** to create self-driving vehicles.

In combination, these trends could lead to the deployment of connected and autonomous vehicles (CAVs). We define *connected vehicles* (CVs) as vehicles that can exchange information wirelessly with other vehicles, infrastructure, the vehicle manufacturer and third-party service providers. *Autonomous vehicles* (AVs) are self-driving vehicles that learn and adapt to dynamic environments and evolve with the environment[111]. There are various use cases linked to both technologies. Some, like advanced driver-assistance systems (e.g. parking assistants, cruise control), are already in use. Others, such as truck platooning, robo-taxis and shuttles, are being tested on roads but still lie further in the future.

Most of our interviewees expected that CAVs will not only be a premium segment but also a volume segment. Initial applications will likely be more expensive, but can with the scaling up of production or in their application of public transportation, reach a wider audience. However, considering current barriers (technical, legal, public acceptance), **widespread deployment of CAVs is not expected**

[108] PwC, 2018, *Five trends transforming the Automotive Industry*. Available at: https://www.pwc.com/gx/en/industries/automotive/assets/pwc-five-trends-transforming-the-automotive-industry.pdf.

[109] Vdovic, H., Babic, J., and Podobnik, V., 2019, *Automotive Software in Connected and Autonomous Electric Vehicles: A Review*," IEEE Access, vol. 7, pp. 166365-166379 Available at: https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8901126.8.

[110] Already, between 2010 and 2019 the number of Electronic Control Units has dropped from an average of 70 to low as 3.

[111] In contrast, automated systems run within a well-defined set of parameters and are restricted in what tasks they can perform in that environment.

before 2035,[112] with some expecting the major benefits of CAVs (increased safety, efficiency, energy conservation and pollution reductions) becoming only visible in the 2040s to 2060s when CAVs will have become sufficiently affordable also for low-income people[113]. There is, therefore, an ongoing process taking the industry from vehicles with driver support features (SAE 2 level) to fully connected and automated vehicles (SAE 5)[114]. This process is already having impacts on the industry and affecting traditional manufacturers and suppliers.

b. Changing industry dynamics

An important impact has been a change in the competition dynamics, **with the novel technologies allowing new entrants in the automotive sector**. One interviewee with a background in automotive R&D noted that the previous high barriers to entry – with well-established players for the ICE – have been lowered due to this new technology cycle. Table A.1 in the Annex provides a broad overview of the key companies (incl. newcomers). The table highlights the importance of large US (Alphabet, Amazon, Microsoft, Intel, Nvidia) and Chinese (Tencent, Alibaba, Huawei, Baidu) technology companies. However, also European (in particular German) OEMs are among the relevant actors.

For the development of CAVs, we pay particular attention to the strategic competencies in software architecture, connectivity and autonomous driving. Especially, the foremost is essential in order to manage the increasing complexity from the integration of new connectivity and autonomous functions. Using data from CAM[115], we find, however, **that in all three areas, no European OEMs can be considered top-innovators**.

Nevertheless, for **software architecture**, BMW is among the innovating companies (through its existing vehicle software, the Operating System 7). Strategically though, Tesla is the best placed as its vehicles are being manufactured with a central control unit and software already in place facilitating over-the-air (OTA) updates. Alphabet, while not manufacturing vehicles itself, is also well placed due to its Android Automotive Operating System (OS) and access to the Google ecosystem. OEMs such as the Chinese Geely (Volvo, Polestar) are already using Alphabet's OS, and others are planning to do so (GM, PSA, Renault, Nissan). Meanwhile, other manufacturers developed their own vehicle software architecture (i.e. BMW), or are in the process of developing one (the VW Group with vw.os and Daimler with MB.OS).

For **connectivity,** both BMW and the VW Group are innovators (specifically through innovative capabilities in user interfaces and Vehicle-to-everything (V2X)). Similar here, though, top innovators are the companies with existing digital ecosystems (Tesla, Alphabet and Alibaba). Despite lacking such digital ecosystems, German OEMs such as the VW Group, BMW and Daimler are also relatively well-placed. Some automotive OEMs are fast following this trend (GM, Hyundai, Toyota), however many others are currently not well placed as they lack competencies, strategic partnerships and financial reserves for investments (e.g. Renault, Nissan).

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112 Ecorys, TRT Srl and M-Five GmbH, VTT, SEURECO, ERTICO-ITS Europe, IRU Projects and UITP,2020, Study on exploring the possible employment implications of connected and automated driving. Available at: https://www.ecorys.com/sites/default/files/2021-03/CAD_Employment_Impacts_Main_Report.pdf.

113 Litman, T.. 2021, *Autonomous Vehicle Implementation Predictions Implications for Transport Planning*, Victoria Transport Policy Institute. Available at: https://www.vtpi.org/avip.pdf.

114 The Society of Automobile Engineers (SAE) defines automation levels starting from SAE levels 0 to 2 (driver support features) to levels 3, 4 and 5 (automated driving features) with the vehicle at levels 3 and 4 taking over driving under limited conditions and under all conditions at level 5. For more information see SAE, 2019, SAE Standards News: J3016 automated-driving graphic update. Available at: https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic/.

115 Bratzel, S.; Tellermann, R.: CCI 2021 – Connected Car Innovation Studie. Center of Automotive Management, Bergisch Gladbach.

This is also the case for many suppliers as they often lack financial reserves and also find it difficult to get financing from banks, as explained by an interviewee from a supplier company.

Finally, for **autonomous driving**, technology companies are the leading innovators. OEMs, apart from General Motors in the USA, are only following this trend currently. Strategically, US companies such as Alphabet with their subsidiary Waymo, Intel with Mobileye and Amazon with Zoox are best placed with them combining software and hardware know-how with data competencies and large testing fleets. Still, OEMs such as the VW Group, Tesla and Hyundai have been growing their own competencies through investments. For example, the VW Group through its joint venture with Ford (ArgoAI).

Apart from one interviewee representing an OEM, our interviewees confirm that the EU automotive sector is behind in these areas. In particular, they cite dependencies on software and data from third parties and the market power of large digital companies as a concern. However, all are also positive that the EU sector can build on its expertise in vehicle engineering and has the resources to catch up and improve its position in the new technology areas. Table 3.1 summarises the positioning of key companies in the three strategic fields.

Table 3.1: Strategic competencies and positioning of key companies

Rank	Software architecture	Connectivity	Autonomous driving
Top-Innovator	• Tesla	• Tesla • Alphabet (Android Automotive) • Alibaba (AliOS)	• Alphabet (Waymo)
Innovator	• Alphabet • BMW	• Amazon (AWS, Alexa) • VW Group • BMW	• Intel (Mobileye) • Amazon (Zoox) • GM (Cruise) • Baidu • Pony.AI
Fast follower	• Alibaba • VW Group • Daimler • Toyota • Geely	• Apple (CarPlay) • Microsoft (Azure, MCVP) • Tencent (WeChat, QQ) • Baidu (CarLife) • GM • Hyundai • Toyota	• VW Group (Argo AI) • Tesla • Hyundai • Didi Chuxing • Microsoft • BMW • Daimler • Apple (Drive. AI) • Toyota

Rank	Software architecture	Connectivity	Autonomous driving
Follower	• Amazon • Microsoft • Hyundai • GM • PSA • Renault • Nissan	• Renault • Nissan	• AutoX • Uber • Renault • Nissan

Source: CAM (2021).

These changes are disrupting the industry, making it more diverse with increased competition. However, one should not neglect the importance of well-established automotive brands in their ability to reach the consumer. In addition, it is expected that consolidation will eventually follow with a few key players and their combined vehicle and service offers dominating the market. Who these players will be depends on the readiness of the current industry, including its factor conditions.

3.1.2 Factor conditions

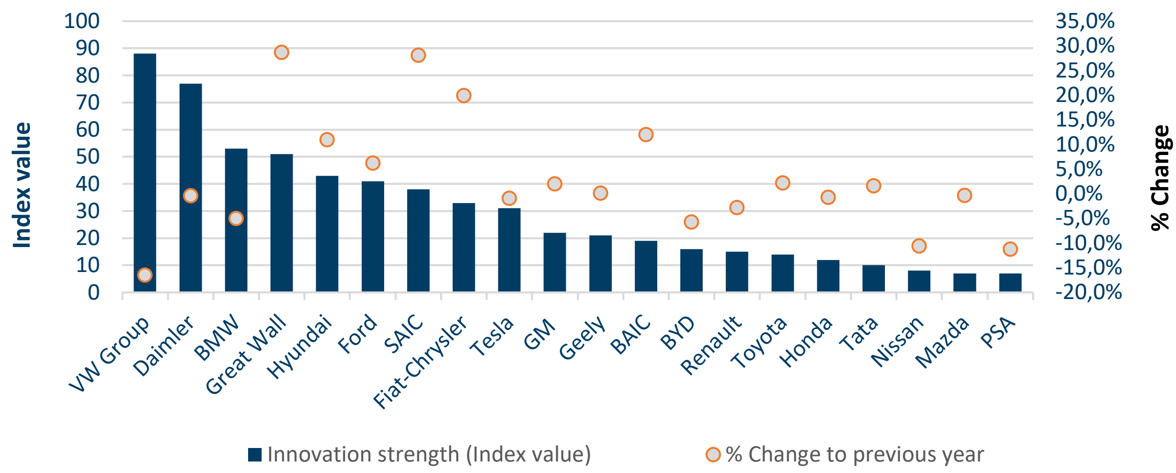
In light of digital technologies disrupting the sector and new entrants entering the market, the right factor conditions, such as labour, investment and innovation, can distinguish the EU automotive sector from its global competitors. In the following sub-sections, we will therefore look at the access of the EU sector to the right factors to stay competitive.

a. Innovation capabilities

Considering the move from hardware to software and the ensuing disruptions from digital technologies described in sections 3.1.1, innovation capabilities are a key factor in the competitiveness of the EU automotive industry. During the past decade, **innovation connectivity and autonomous driving have been accelerating**.

Looking at the current innovation landscape, innovation in these areas are led by a few European and Asian OEMs, namely VW Group, Daimler, BMW, Great Wall and Hyundai. Figure 3.1 presents the ranking of OEMs in innovation strength based on calculations by CAM. It showcases the good positioning of European manufacturers, but also the increasing importance of Chinese manufacturers with the fast rise of Great Wall and SAIC. Compared to their ranking of the previous year, both managed to improve their innovation strength by close to 30%, while EU OEMs apart from Fiat-Chrysler (now Stellantis) lost in innovation strength.

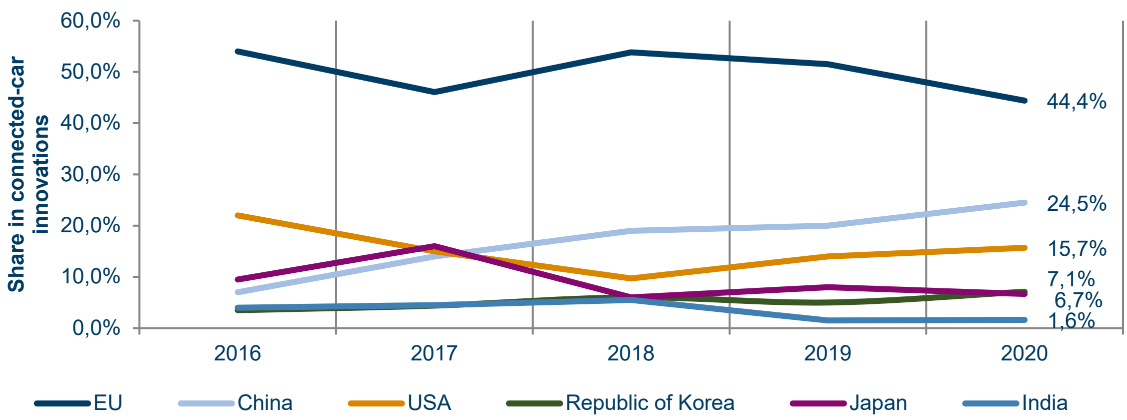
Figure 3.1: Top 20 OEMs in CAVs innovation strength 2020



Source: CAM (2021). Note: PSA and Fiat-Chrysler merged in January 2021 and became Stellantis. CAVs include the technologies of ADAS/safety, connectivity and interfaces.

The above figure already paints an image of European automotive OEMs losing their leadership positions. This is also showcased when looking at a country level. European OEMs are currently clearly leading in terms of innovation. However, increasingly, innovation in CAVs is originating in third countries, specifically China and the USA (see Figure 3.2). Likely, the strength of Chinese and American ICT companies contributes to innovation in this area. In contrast, EU companies are said to lag behind in adopting digital technologies compared to their American counterparts[116]. The autonomous vehicle readiness index even ranks Israel, the USA and Japan ahead of EU countries such as Germany, Sweden and Finland in technology and innovation. However, China, with rank 20, is less well placed in that ranking[117].

Figure 3.2: Share of CAVs innovations by country/region



Source: CAM (2021). Note: CAVs include the technologies of ADAS/safety, connectivity and interfaces.

[116] EIB,2020, *Who is prepared for the new digital age? Evidence from the EIB Investment Survey*. Available at: https://www.eib.org/en/publications/who-is-prepared-for-the-new-digital-age.

[117] KPMG, 2020, *2020 Autonomous Vehicles Readiness Index*. Available at: https://assets.kpmg/content/dam/kpmg/uk/pdf/2020/07/2020-autonomous-vehicles-readiness-index.pdf.

This increased importance of ICT in driving innovation can be seen in patent data. Between 2011 to 2017, 30.4% of the patents registered in the area of computing for automated vehicle platforms came from ICT companies (33.6% from automotive ones). Even higher, 42.6% of communication patents in-vehicle connectivity came out of the ICT sector (18.5% from automotive). According to data from the European Patent Office, companies such as Samsung, Intel, Qualcomm, LG, Nokia, and Ericsson are key contributors to the development of CAVs next to traditional automotive companies such as Bosch, Toyota, Continental, Volvo and Audi[118]. Looking at the geographical origin of CAV innovation, Europe is leading with 37.2% of patents, closely followed by the USA (33.7%), Japan (13.3%), the Republic of Korea (7.3%) and China (3.2%).

b. Investment in digital technologies

In order to grow innovation capabilities, investments are needed. In fact, the R&D intensity of the European automotive sector (EUR 62 billion in 2019) is far ahead compared to its Japanese (EUR 34 billion), US (EUR 17 billion) and Chinese (EUR 9 billion) counterparts. Among the top 10 EU companies in R&D investment, there are five automotive companies (VW Group, Daimler, BMW, Robert Bosch, and Fiat). However, as discussed above, the ICT sector's importance in automotive innovation is growing. Moreover, global R&D investment in both ICT hardware and services have surpassed automotive investments, and while the EU is outperforming the USA, China and Japan in automotive, both the USA and China outperform the EU in ICT R&D[119].

Still, it was pointed out in interviews that European automotive OEMs increasingly invest in their own software solutions.

For example, the VW Group aims to invest EUR 7 billion to develop a dedicated software team driving the continued development of its OS[120]. This will be crucial for the competitive position of the EU automotive sector, as according to a PwC report, companies investing in R&D for software solutions show stronger growth than their competitors[121]. It is unclear if these investments are enough, as also the European Partnership on Connected and Automated Driving (CCAM) listed inadequate investment levels in innovation as a challenge[122]. In addition, not all OEMs have the financial resources to make the required investments. **Therefore, cooperation and joint ventures between OEMs and digital companies are required for the EU automotive sector to ensure sufficient investments are made**[123].

Beyond investment from the sector itself, financial companies and investors also play a large role. Between 2010 and 2020, USD 166.6 billion has been invested into CAV technologies (primarily in semiconductors, ADAS, and infotainment). Most of this investment did not come from the sector but

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[118] EPO and EUCAR, 2018, *Patents and self-driving vehicles: The inventions behind automated driving*. Available at: https://www.lemoci.com/wp-content/uploads/2018/11/OEB-EPO-Self-driving-vehicles-study.pdf.

[119] Joint Research centre, 2020, *The 2020 EU Industrial R&D Investment Scoreboard, European Commission*, European Commission.
Available at: https://iri.jrc.ec.europa.eu/scoreboard/2020-eu-industrial-rd-investment-scoreboard.

[120] Volkswagen, 2020, *Leading the Transformation*. Available at: https://www.volkswagenag.com/presence/investorrelation/publications/presentations/%202020/03-%20m%C3%A4rz/2020.02.27_VWAG_Exane_Webcast%202020.pdf.

[121] PwC (2018) Five trends transforming the Automotive Industry. Available at: https://www.pwc.com/gx/en/industries/automotive/assets/pwc-five-trends-transforming-the-automotive-industry.pdf.

[122] ERTRAC, 2020, *Connected, Cooperative and Automated Mobility (CCAM)*.. Available at: https://www.ertrac.org/uploads/images/CCAM%20Info%20Day%2023-11-2020.pdf.

[123] Bratzel, S.; Tellermann, R.: CCI 2021 – Connected Car Innovation Studie. Center of Automotive Management, Bergisch Gladbach.

from venture capital and private equity, as well as technology companies[124]. According to McKinsey & Company, the majority of these mobility investments go to US (USD 84.5 billion), Chinese (USD 51 billion) and UK (USD 34 billion) companies. Only USD 10.7 billion went to EU companies[125]. A lack of venture capital is often voiced as a concern for Europe. Some of the interviewees, while echoing this concern, also stated that the overall investment climate is good and improving. In fact, a study by the Joint Research Centre (JRC) showed that venture capital is growing substantially in the EU, even though overall Europe is still lagging[126].

c. Supply of skilled labour

Beyond investments, the digital transformation of the sector requires skilled labour. It is estimated that a predicted 13% annual growth in the automotive software market corresponds to a 6% annual increase in demand for software engineers[127].

Numbers from Cedefop highlight this **increasing importance of highly skilled technical jobs (researchers, engineers, ICT professionals) in the automotive sector**, while demand for metal and machinery workers declines[128]. A survey on skill needs in the sector identified big data/data analytics, software development and technical knowledge as the top three skills[129]. Automation, for which the automotive sector is the driving force, can only partially cover this demand as it replaces mainly labour at the assembly line. In addition, about 23% of people employed in the manufacture of motor vehicles are approaching or starting to approach retirement age[130]. To address the issue, the sector already aims to increase its labour force in crucial areas[131].

Delivering a sufficient supply of skilled labour to address the European automotive sector's demand will be crucial. The International Digital Economy and Society Index (I-DESI) highlights that the top-performing EU countries outperform most third countries in digital skills (apart from the USA), with the EU performing particularly well in its high number of ICT graduates. However, on average, the EU is lagging behind third countries in areas such as basic software coding skills.[132] Despite the high

[124] McKinsey & Company, 2021, *Mobility's future: An investment reality check*. Available at: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/mobilitys-future-an-investment-reality-check.

[125] McKinsey & Company, 2019, *Start me up: Where mobility investments are going*. Available at: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/start-me-up-where-mobility-investments-are-going

[126] Bellucci, A., Gucciardi, G. and Nepelski, D., 2021, *Venture Capital in Europe. Evidence-based insights about Venture Capitalists and venture capital-backed firms*,Joint Resource Centre. Available at: https://publications.jrc.ec.europa.eu/repository/handle/JRC122885.

[127] McKinsey, 2020, *Rethinking European Automotive Competitiveness. The R&D CEE opportunity*. Available at: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/rethinking-european-automotive-competitiveness-the-r-and-d-cee-opportunity.

[128] Cedefop, 2021, *Automotive industry at a crossroads*. Available at: https://skillspanorama.cedefop.europa.eu/en/analytical_highlights/automotive-industry-crossroads#_the_rise_of_european_automotive_industry.

[129] DRIVES, 2019, *Insights of the Automotive Sector 2019. Deliverable 2.7 Forecasting Dissemination Report*. Available at: https://www.project-drives.eu/Media/Publications/10/Publications_10_20190918_195654.pdf.

[130] CLEPA, IndustriAll and ETRMA (2013) European Sector Skills Council Automotive Industry.

[131] For example, VW aims to increase its team of inhouse software experts by 46% until 2025. Source: Volkswagen, 2020, *Leading the Transformation*. Available at: https://www.volkswagenag.com/presence/investorrelation/publications/presentations/%202020/03-%20m%C3%A4rz/2020.02.27_VWAG_Exane_Webcast%202020.pdf.

[132] Tech4i2, 2021, 2020 International Digital Economy and Society Index - SMART 2019/0087, Luxembourg, Publications Office of the European Union. Available at: https://digital-strategy.ec.europa.eu/en/policies/desi.

number of graduates, the EU lacks already around 1 million ICT specialists, and this figure could grow to 2 million by 2030 with the skill shortage affecting especially SMEs[133].

The 2030 Digital Compass notes that demand is expected to increase faster than supply, highlighting that over 70% of businesses report a lack of staff with adequate digital skills[134]. Interviewees from the automotive sector confirmed that it is getting more and more difficult to find and attract the right talent. In light of this, **a key challenge for the EU will be to provide and attract sufficient talent in these new technology areas**. Potential solutions include making the sector more attractive for younger people and especially women and making use of the potential workforce in Central and Eastern Europe through near-sourcing. There is also the potential of reskilling workers whose positions are endangered by the transition to electromobility. However, as discussed in section 2.1.2, there are currently different views on the exact labour impacts, with some studies predicting job losses and others expecting that these will be covered by the creation of new jobs.

Box 3.1: Labour impacts of CAVs

Expected labour impact of CAVs in transport and manufacturing

Labour is also heavily affected by these technological developments. The introduction of CAVs will impact employment not only in manufacturing but also in road transport services. Freight and passenger road transport is expected to be impacted negatively, with many of the over 6 million workers being replaced by automated freight services and robo-taxis, robo-shuttles and shared services. In scenarios with high uptake of shared service, EU employment in passenger transport services could decrease by 12.5% by 2050. In freight transport, the scenario with the fastest deployment of CAVs sees a reduction of 58%. CAV technologies will, however, not only reduce the demand but could also make driving jobs more attractive, turning professional drivers into mobility operators and thereby potentially addressing the existing driver shortage.

Employment gains from CAVs in the vehicle manufacturing, electronics, ICT and construction sectors are not expected to make up for employment losses in transport services by far. Overall the manufacturing employment is declining; however, this does not apply to CAV-related manufacturing. In CAV, manufacturing employment will increase, driven by the growing employment opportunities in electronics. It is expected that the total sectoral employment in electronics will increase by 3.22% between 2020 and 2050. Such employment gains will likely also be centred around a few regions that currently have a strong presence of automotive OEMs (e.g. Île-de-France, Upper Bavaria and Stuttgart) or of suppliers (e.g. Noord-Brabant and Dresden for semiconductors or Stockholm for CAV technologies).

Sources: Ecorys, TRT Srl and M-Five GmbH, VTT, SEURECO, ERTICO-ITS Europe, IRU Projects and UITP (2020) Study on exploring the possible employment implications of connected and automated driving.
Alonso Raposo, M., et al, The future of road transport - Implications of automated, connected, low-carbon and shared mobility, EUR 29748 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-03409-4, doi:10.2760/9247, JRC116644.

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[133] Capgemini Invent, European DIGITAL SME Alliance, Technopolis Group, 2020, *Skills of SMEs. Supporting specialised skills development: Big Data, Internet of Things and Cybersecurity for SMEs,* European Commission. Available at: https://skills4industry.eu/sites/default/files/2021-05/EA0420007ENN_en.pdf.

[134] The Digital Compass was released in 2021 and sets out the vision for making 2030 a decade of empowering citizens and businesses through a digitalised economy. One of its key priorities is skills. For more information, see: European Commission, 2021, 2030 Digital Compass: the European way for the Digital Decade.
Available at: https://digital-strategy.ec.europa.eu/en/policies/digital-compass.

3.1.3 Demand conditions

Both the amount and the type of demand can be important factors in an industry's willingness and ability to innovate and become more competitive. **Vehicle technologies are generally considered slow in penetrating markets compared to other consumer goods** due to their costs, durability, and regulation. Initially, CAVs are likely to be expensive and limited in their performance, which will reduce demand [135]. Moreover, the CCAM partnership identified insufficient demand due to a lack of acceptance for the transition as a key barrier[136].

Demand for vehicle software and CAVs is considered to be driven by[137]:

- **Energy and cost efficiency** through replacing existing hardware functions with software or by adding intelligent predictive management functions;
- **Zero accidents** through pro-active safety functions, with the ultimate solution being fully autonomous vehicles;
- **Seamless connectivity** with vehicles connected to smart devices and the cloud, and receiving frequent software updates; and
- **Personalisation** with secondary vehicle functions being transferred to personal mobile devices to provide users with information about their vehicle.

There are, however, two main barriers to the deployment of CAVs in Europe. One is user acceptance, and the other is the availability of infrastructure to test and roll out the vehicles. In addition, the increasing importance of shared services is expected, inducing a shift from owning cars towards using them and thereby potentially to less vehicle demand.

a. User Acceptance

The adoption of autonomous vehicles (AVs) heavily relies on end-user acceptance. It is, therefore, crucial to understand what affects acceptance. Research has led to the identification of five main factors: trust[138], price, willingness to pay[139], driving pleasure and safety[140].

A report produced by Ericsson[141] reveals that the sense of freedom and autonomy that cars offer are two of the most common reasons among users for not embracing AVs, as "driverless cars would take all the fun out of driving". It seems that people are not ready yet to fully trust a vehicle's software to

135 Litman, T., 2021, *Autonomous Vehicle Implementation Predictions Implications for Transport Planning*, Victoria Transport Policy Institute. Available at: https://www.vtpi.org/avip.pdf.

136 ERTRAC, 2020, *Connected, Cooperative and Automated Mobility (CCAM)*.. Available at: https://www.ertrac.org/uploads/images/CCAM%20Info%20Day%2023-11-2020.pdf.

137 Buckley, C., et al., 2021, *The software car: Building ICT architectures for future electric vehicles*, IEEE International Electric Vehicle Conference, pp. 1-8.Available at: http://mediatum.ub.tum.de/doc/1285769/591565.pdf.

138 Benleulmi, A. et al., 2017. *Investigating the factors influencing the acceptance of fully autonomous cars.* Available at: https://www.econstor.eu/bitstream/10419/209304/1/hicl-2017-23-099.pdf.

139 Bansal, P. et al., 2017. *Forecasting Americans' long-term adoption of connected and autonomous vehicle technologies.* Transportation Research Part A: Policy and Practice. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0965856415300628.

140 Gkartzonikas, C. et al., 2019. *What have we learned? A review of stated preference and choice studies on autonomous vehicles*. Transportation Research Part A: Policy and Practice. Available at: https://www.sciencedirect.com/science/article/pii/S0968090X18303589.

141 Ericsson, 2017, *The Self-Driving Future: Consumer views on letting go of the wheel and what's next for autonomous cars.* Available at: https://www.ericsson.com/49e8eb/assets/local/reports-papers/consumerlab/reports/2017/ericsson-consumerlab-driving-report.pdf.

make their driving decisions. Still, many people are interested in self-driving functionalities such as parking assistance and cruise control. Furthermore, one in four pedestrians claimed that they would feel safer with AVs[142]. **Overall though, research shows a trend towards increased willingness to use automated vehicles,** with the acceptance being higher among men, young people and in urban areas. In 2017, 52 to 63% of users said they would feel uncomfortable being in an AV, while in a previous survey, the number was around 70%[143].

Despite increasing awareness seemingly improving acceptance, there is also larger attention towards accidents that involve AVs. Recent incidents have been widely publicised and dampened general acceptance. **Future accidents could pose a risk towards future demand**. Therefore, the aim is to minimise such accidents by adopting the highest safety and security standards[144].

b. Testing autonomous vehicles

Autonomous vehicles are not part of our lives yet, and before that happens, they need to be tested. Currently, the pace at which self-driving cars are being tested has slowed down due to two fatality incidents[145]. The incidents have raised concerns about whether artificial intelligence is able to replace human decision-making.

Testing CAVs was difficult even before that. To begin with, there has been an ongoing debate about the extent of testing needed. In 2016, a study by RAND Corporation found that the number of miles needed to prove that autonomous vehicles' performance meets and/or exceeds the performance of human driving could be as high as 275 million, which is equivalent to billions of hours on the road[146]. This is because there is an infinite number of different scenarios that a self-driving car could experience, such as different weather conditions or different levels of danger. Most of these scenarios cannot be reproduced in real life, at least not in less than dozens of testing years[147]. Data collection poses an issue for real-life testing as it is very time-consuming and costly. As a result, simulation is the only option for testing. Nevertheless, although a valuable technology for safety testing of autonomous vehicles, its sufficiency is debatable, particularly after the recent accidents.

Furthermore, regulatory barriers to testing CAVs are also an ongoing issue. The first OEM that has received formal approval to introduce automatic driving on the public road is Honda. In Europe, Daimler is planning to introduce automatic driving technology into the German market with Drive Pilot towards the end of 2021. In order to get the S-Class approved for the public road, a legal framework has to be created. However, this could be a challenge, as the failure of the legal framework caused Audi's AI Traffic Jam Pilot to fail in 2017[148]. Recently though, in Germany, a new law was approved that could bring autonomous vehicles into regular operation by 2022[149].

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142 Ibid.

143 Alonso Raposo, M., et al, The future of road transport - Implications of automated, connected, low-carbon and shared mobility, EUR 29748 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-03409-4, doi:10.2760/9247, JRC116644.

144 Ibid.

145 A pedestrian struck by an autonomous vehicle in 2018 and an accident with a Tesla involved in April 2021.

146 Kalra, N., et al, 2016, Driving to Safety: How Many Miles of Driving Would It Take to Demonstrate Autonomous Vehicle Reliability? Available at:https://www.rand.org/pubs/research_reports/RR1478.html.

147 SIEMENS, 2018,, The challenges with autonomous vehicle testing. Available at: h https://blogs.sw.siemens.com/thought-leadership/2018/11/28/the-challenges-with-autonomous-vehicle-testing/.

148 Center of Automotive Management (CAM). (2021). Innovation dynamics and success factors in the automotive industry An analysis of the future trends in the fields of connectivity, autonomous driving and mobility services.

149 Ayad, P., Göpferich, K., Schuster, S. and H. Lovells, 2021, Germany takes the lead with a new law on autonomous driving and update. Available at: https://www.jdsupra.com/legalnews/germany-takes-the-lead-with-a-new-law-7746782/.

Despite some policy developments since then, two prominent issues in the European legislative environment have been identified:

- **The knowledge gap**: self-driving technology is rapidly evolving, and it is difficult for laws and regulations to always reflect the most recent developments. Both companies in the automotive industry and regulators would benefit from closer collaboration with each other, to be informed and keep up to date; and
- **Lack of large-scale testing**: contrary to the USA, a supportive regulatory environment for large-scale public testing is missing in Europe, and only a few Member States have introduced policies. Deploying large fleets of CAVs in live situations is not a possibility at the moment, resulting in delays in both testing and launching automated vehicles.

Testing practices or regulatory frameworks for testing are not globally harmonised, e.g. safety regulations while test-driving differ between countries[150]. However, the 1968 Vienna Convention on Road Traffic was amended in 2016 to also allow the automated operation of vehicles.

In Europe, not all countries follow the same procedures. However, the EC published guidelines for the approval of automated vehicles.

AV testing on the public road as of 2019 was legalised in France, Germany, the Netherlands, Norway, Sweden, and the UK. Testing on public roads is also legal in the USA, Japan and China[151]. Tests on public roads have been conducted in Europe and third countries since the early 2010s. For example, Nissan conducted the first public road test of an automated vehicle on a Japanese highway in 2013, while Google and Toyota were the first to test an AV in the USA in 2012[152]. Despite these challenges, five European countries (the UK, the Netherlands, Finland, Germany and Norway) are among the top ten in the policy and legislation pillar of the Autonomous Vehicles Readiness Index[153].

c. Shared services

Shared services of autonomous vehicles are an integral part of the discussion. PwC predicts that the market share of autonomous shared concepts in Europe could increase by over 70% between 2022-2030 per year, making up more than 25% of mobility forms by 2030[154]. This shift is expected to also decrease private-vehicle sales, especially in urban areas, where there are many opportunities for new

[150] Lee, D., & Hess, D. J.,2020, *Regulations for on-road testing of connected and automated vehicles: Assessing the potential for global safety harmonization*. Transportation Research. Part A, Policy and Practice, 136, 85–98. Available at: https://research.utwente.nl/en/publications/regulations-for-on-road-testing-of-connected-and-automated-vehicl.

[151] SMMT, 2019, *Connected and Autonomous Vehicles: Winning the global race to market*. Available at: https://www.smmt.co.uk/reports/connected-and-autonomous-vehicles-the-global-race-to market/#:~:text=Connected%20and%20Autonomous%20Vehicles%3A%20Winning,increasing%20CAVs%20on%20our%20roads.&text=2%20Combined%20with%20the%20gradual,will%20deliver%20massive%20safety%20benefits.

[152] Ecorys, TRT Srl and M-Five GmbH, VTT, SEURECO, ERTICO-ITS Europe, IRU Projects and UITP, 2020, *Study on exploring the possible employment implications of connected and automated driving. Annexes.* Available at: https://www.ecorys.com/sites/default/files/2021-03/CAD_Employment_Impacts_Annexes.pdf.

[153] KPMG, 2020, *2020 Autonomous Vehicles Readiness Index*. Available at: https://assets.kpmg/content/dam/kpmg/uk/pdf/2020/07/2020-autonomous-vehicles-readiness-index.pdf.

[154] PwC, 2018, *Five trends transforming the Automotive Industry*. Available at: https://www.pwc.com/gx/en/industries/automotive/assets/pwc-five-trends-transforming-the-automotive-industry.pdf.

mobility services. Sales in shared vehicles could, however, partially offset the drop in sales as these would need to be replaced more often due to their higher utilisation rates[155].

Much of the literature predicts that **private vehicles will continue to exist and will dominate the market for at least the next 30 years**. Nonetheless, a recent study argues that so-called 'robo-taxis' for urban use will affect future mobility behaviour and may have a significant impact on the notion of private-owned cars[156]. Studies show that 40% of people are willing to use shared autonomous vehicles (SAVs) for 80% of their trips, and 44% are willing to use them for 50% of their trips[157].

SAVs are estimated to have greater capacity than conventional vehicles currently do, resulting in a significant annual mileage increase. It is also predicted that by 2030, more than one in three kilometres driven may be through shared services. Notably, in the important Chinese market, the adoption rate is estimated to be fast, with 45% of the total personal mileage covered by shared vehicles by 2030[158].

The greater capacity and higher intensity of use of SAVs could significantly alter the total vehicle stock.

Based on the scenario that by 2030, 25% of mobility forms are SAVs, PwC calculated that Europe's vehicle stock of 280 million vehicles could decrease to 200 million by 2030. Overall, although it is difficult to quantify the extent of replacement of private ownership, it is suggested that SAV systems can potentially reduce ownership when supported by adequate policies.

3.1.4 Related and supporting industries

There are various industries supporting the development of CAVs. Important supporting industries are data and software providers, sensors and camera equipment manufacturers, as well as infrastructure providers for connectivity applications. However, specifically, when looking at the combined impact of electrification and the digitalisation of vehicles, then semiconductors and the electronics industry are key supporting industries.

Between 1998 and 2015, the **increasing importance of electronics in vehicles has led to a threefold increase in automotive semiconductor sales.** A Roland Berger study indicates that the share of electronic components on the overall vehicle value in 2019 stood at 16% for ICE vehicles, and it is estimated to increase to 35% for BEVs by 2025[159]. This percentage is expected to further rise to 50% by 2030[160]. The increasing importance of electronics is leading to **structural changes in the automotive value chain**.

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[155] McKinsey (2016) Automotive revolution – perspective towards 2030. Available at: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/disruptive-trends-that-will-transform-the-auto-industry/de-DE.

[156] Heineke, Kersten, et al., 2019, *Change vehicles: How robo-taxis and shuttles will reinvent mobility*. Available at: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/change-vehicles-how-robo-taxis-and-shuttles-will-reinvent-mobility/.

[157] Webb, J., Wilson, C., & Kularatne, T,. 2019, *Will people accept shared autonomous electric vehicles? A survey before and after receipt of the costs and benefits*. Economic Analysis and Policy, 61, 118–135. Available at: https://ideas.repec.org/a/eee/ecanpo/v61y2019icp118-135.html.

[158] PwC, 2018, *Five trends transforming the Automotive Industry* Available at: https://www.pwc.com/gx/en/industries/automotive/assets/pwc-five-trends-transforming-the-automotive-industry.pdf.

[159] Meissner, F. et al., (2020). Computer on wheels: disruption in automotive electronics and semiconductors. *Focus Roland Berger*.

[160] Statista Research Department (2021). Automotive electronics cost as a percentage of total car cost worldwide from 1970 to 2030. Available at: https://www.statista.com/statistics/277931/automotive-electronics-cost-as-a-share-of-total-car-cost-worldwide/

In some cases, semiconductor manufacturers move up the value chain, moving towards functional integration of their chips and by also providing automotive software (e.g. through Intel's Mobileye). Simultaneously, OEMs aim to increase control over the value chain (e.g. through in-house software development and semiconductor design). This puts especially traditional tier-one suppliers under pressure, who need to consider their role in software and electronics integration[161].

The value chain for electronics is one that is becoming heavily globalised, with close to 80% of semiconductor foundries being concentrated in Asia while the high-tech market for electronics is dominated by US companies[162]. **This global value chain was recently disrupted by the COVID-19 pandemic and the China-USA trade tensions,** causing uncertainties that led to double-booking by semiconductor foundry clients to build inventories[163]. Further strain was put on the supply of semiconductors by a drought impacting their production in Taiwan. This has also affected automotive manufacturers who initially reduced their orders during the pandemic[164], which was more than offset by increased demand from consumer electronics.

With the recovery and an ensuing surge in demand from automotive manufacturers, semiconductor foundries already at capacity are now struggling to meet the high demand[165].

As highlighted in Figure 3.3, **the shortage has led to a sharp increase in delivery times for the automotive sector**, which in turn has led to a decline in vehicle production. In the first quarter of 2021, global vehicle production fell by 1.3 million vehicles (11.3% decline)[166]. The shortage seems to persist for now as only in July 2021 it was reported that Daimler was forced to put thousands of workers on short-time work[167].

161 Meissner, F. et al., (2020). Computer on wheels: disruption in automotive electronics and semiconductors. *Focus Roland Berger*.

162 Ecorys, CEPS, 2021, *Impacts of the COVID-19 pandemic on EU industries*, European Parliament, Policy Department for Economic, Scientific and Quality of Life Policies Directorate-General for Internal Policies. Available at: https://www.europarl.europa.eu/RegData/etudes/STUD/2021/662903/IPOL_STU(2021)662903_EN.pdf

163 Singh, M., Y., 2021, *Double Booking Partly Responsible For Uncertainties in Semiconductor Supply*, Electronicsb2b. Available at: https://www.electronicsb2b.com/headlines/double-booking-partly-responsible-for-uncertainties-in-semiconductor-supply/.

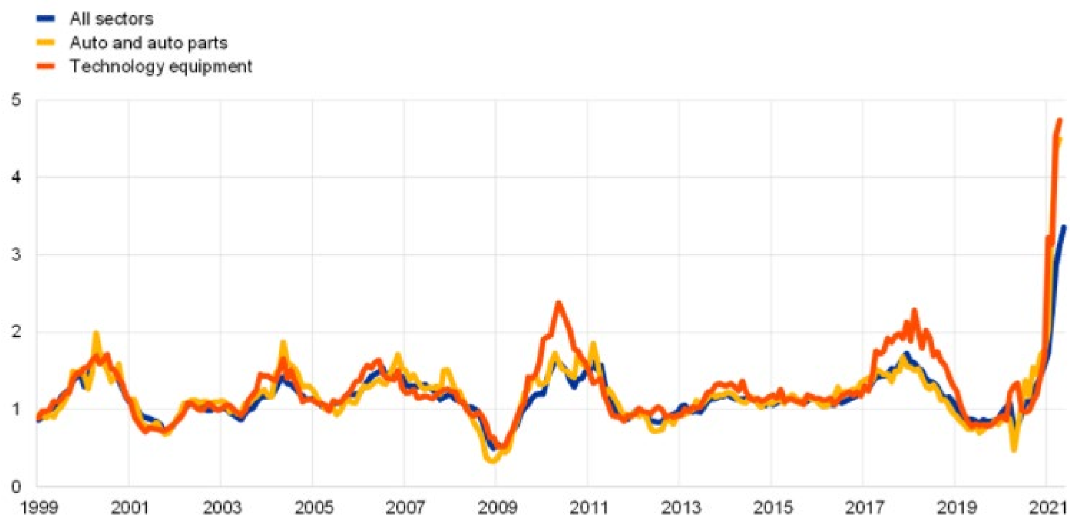
164 Hille, K., 2021, The automotive sector's just-in-time model disincentivises inventory building, contributing to the current shortage as it relies on flexible suppliers which is opposite to the more long-term relationships between fabless chipmakers and semiconductor foundries. Available at: https://www.ft.com/content/7305bf1b-feea-4102-9e2d-08572a7f99c4.

165 ECB, 2021, *The semiconductor shortage and its implication for euro area trade, production and prices*, ECB Economic Bulletin, Issue 4/2021. Available at: https://www.ecb.europa.eu/pub/economic-bulletin/focus/2021/html/ecb.ebbox202104_06~780de2a8fb.en.html/

166 Ibid.

167 Noyan, O., 2021, *German carmakers partially shut down amid semiconductor shortage*, Euractiv. Available at: https://www.euractiv.com/section/digital/news/german-carmakers-partially-shut-down-amid-semiconductor-shortage/.

Figure 3.3: Euro area suppliers' delivery times (ratio of PMI new orders to suppliers' delivery times)



Source: ECB (2021). Note: PMI = Purchasing Manager Index.

Policymakers seem to be reacting to this by pouring money into the industry, supporting both research and production. The USA supports the industry with USD 52 billion, and South Korea even plans to invest USD 450 billion by 2030. Meanwhile, in the EU, Member States formed an alliance committing themselves to funnel funding from the Recovery and Resilience fund into microelectronics. The EU's 2021 Strategic Foresight Report also recognises semiconductors as an area where the EU needs to increase its capacities to develop and produce[168]. The industry itself has also been investing. Bosch's new semiconductor factory recently opened in Dresden, and others such as Intel, TSMC and Samsung are also planning to increase capacities.

However, **traditionally the semiconductor industry has been highly volatile, with booms following busts**[169]. On the one hand, building a semiconductor fabrication plant requires massive capital investments due to the expensive lithography machinery needed. On the other hand, production costs of semiconductors are low, leading to massive economies of scale. Once built, factories are normally run at full capacity in order to break even on the initial investment costs. This can lead to overcapacities if many new factories are built simultaneously[170]. There is a risk that the capacities currently being built might lead to overcapacities and another bust cycle in the future[171].

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168 European Commission (2021) 2021 Strategic Foresight Report. The EU's capacity and freedom to act. COM(2021) 750 final.

169 Tan, H & Mathews, J. A,, 2010, *Cyclical industrial dynamics: The case of the global semiconductor industry*, Technological Forecasting and Social Change, Volume 77, Issue 2,

Available at: https://agris.fao.org/agris-search/search.do?recordID=US201301726567.

170 Köllner, C., 2021, *Das müssen Sie zur Halbleiter-Krise wissen*, Springer.

Available at: https://www.springerprofessional.de/halbleiter/halbleitertechnik/das-muessen-sie-zur-halbleiter-krise-wissen/19356172.

171 See for example, Blodgett D., 28 May 2021, *What's next for Semiconductors? Be wary of those who say, "This is a new paradigm"*,Omdia. Available at: https://omdia.tech.informa.com/blogs/2021/whats-next-for-semiconductors-be-wary-of-those-who-say this-is-a-new-paradigm; Heo S., 2021, *Over-investment into semiconductors amid shortage may lead to overcapacity, warns Natixis*, Asian Business.

Currently, it is unclear how long the shortage will last. Recent reports indicate a worsening with Toyota planning to reduce its production by 40%, and the situation is expected to remain difficult for the remainder of 2021[172]. There are also differing views from the industry. The CEO of ASML, a Dutch company producing lithography machines required to produce semiconductors, believes that the process of catching up will take up until 2022. Intel's CEO echoes this view arguing that it could take a couple of years, while TSMC's chairman is more optimistic, but also expects that due to the time lag in producing automotive chips, it will take the industry into 2021 to catch up[173].

3.2 Other aspects of the digital transformation

3.2.1 Enabling infrastructure for connectivity and automation

Under the term the Internet of Things (IoT), we see a trend of more and more objects becoming connected to the internet. This trend also includes vehicles, which will require an increasing amount of data to be exchanged. The expected amounts of data generated in an AV vary widely from 3.2 gigabytes to 32 terabytes a day[174]. In either case, connectivity and automation **will require a safe, secure and reliable infrastructure capable of high-speed data transfer** mobile communication standards. 5G could provide such an infrastructure, and already in 2020, there were about 393,000 vehicles with an embedded 5G IoT endpoint installed. It is expected that by 2023 this number will increase to over 19 million[175]. Simultaneously, infrastructure is also being rolled out. According to the EU 5G Observatory, 5G deployment is progressing well in Europe with 5G services available in 25 EU Member States and 12 cross-border 5G corridors have been established to accommodate tests of 5G for CAVs[176].

[172] Beacham, W., 2021, *Semiconductor shortage persists, hurting automotive production, chemicals, ICIS.* Available at: https://www.icis.com/explore/resources/news/2021/08/30/10679631/semiconductor-shortage-persists-hurting-automotive-production-chemicals.

[173] Timings, J. (2021), *The world's short on chips, the semiconductor industry is up for the challenge, ASML*. Available at: https://www.asml.com/en/news/stories/2021/global-chip-shortage-challenge.

[174] Mellor, C., 2020, *Data storage estimates for intelligent vehicles vary widely, Blocks and files*. Available at: https://blocksandfiles.com/2020/01/17/connected-car-data-storage-estimates-vary-widely/.

[175] Gartner, 2019, *Gartner Predicts Outdoor Surveillance Cameras Will Be Largest Market for 5G Internet of Things Solutions Over Next Three Years*. Available at: https://www.gartner.com/en/newsroom/press-releases/2019-10-17-gartner-predicts-outdoor-surveillance-cameras-will-be.

[176] European 5G Observatory, 2021, *5G Observatory Quarterly Report 12 Up to June 2021*. Available at: https://5gobservatory.eu/wp-content/uploads/2021/07/90013-5G-Observatory-Quarterly-report-12_v1.0.pdf.

Box 3.2: 5G in automotive manufacturing

5G not only is an enabling factor in terms of infrastructure but can also improve production processes through Industry 4.0 applications such as industrial IoT. Machines and logistic chains will benefit from faster and more reliable data transfers. 5G can, for example, be used to allow workers to access machines faster and easier through mobile control panels. Augmented reality could also be more widely used with the new mobile communication standards, allowing workers to use data glasses to view status information in real-time, hence optimally monitoring and maintaining machines. Finally, driverless transport systems can be networked via 5G and integrated into production.

As an example from the automotive sector, the supplier Bosch has created its first 5G campus network. The network was set up jointly with Nokia allowing the company to equip one of its plants with 5G. With reliable high-speed data transfers and ultra-fast machines reacting instantaneously, Bosch aims to make its manufacturing process more efficient. In addition, Bosch also makes its products 5G capable; with the ctrlX Automation platform, Bosch wants to bridge the gap between control, systems, IT, and IoT. Another example is the ActiveShuttle, in which 5G competencies and intelligent software permit it to merge into intralogistics operations smoothly and safely.

Sources: Bosch, 2020, *Bosch puts first 5G campus network into operation*. Available at: https://www.bosch-presse.de/pressportal/de/en/bosch-puts-first-5g-campus-network-into-operation-221632.html.
Bosch, 2021, *5 Gründe für 5G*. Bosch Global. Available at: https://www.bosch.com/de/stories/5g-industrie-4-0/.

In connectivity, two main technology areas can be distinguished, intra-car and inter-car infrastructure. The intra-car infrastructure consists of sensors and wireless subsystems (Car2Car), processing platforms, and the corresponding software services to process real data flows (CV2X, V2V). Inter-car technology, which is used for autonomous driving, requires ICT infrastructure and software applications. For all intra- and inter-car technology, 5G can be used to support application services[177]. For setting up good and reliable infrastructure, already in 2015, the European Commission suggested five key performance indicators (KPIs)[178]:

- **Reliability and availability**: Communication loss or data corruption can have severe consequences for automotive vehicles; hence, telecommunication networks and services must always work;
- **Security**: to prevent hacking or unauthorized access to connected vehicles, secure transmission is crucial;
- **Delay/Latency**: target range 1-10ms. A low end-to-end is critical to assess real-time applications;
- **Bandwidth**: high volumes of data transport are required, especially taking into account a large number of cloud-connected devices and AI services involved in autonomous vehicles; and
- **Topology**: the 5G network topology should be designed properly, considering the specific environment in which the connected or autonomous vehicle is located.

Currently, from the suggested KPIs, **the security indicator represents the main challenge** for the 5G network in the automotive sector[179].

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[177] Mellor, C., 2020, *Data storage estimates for intelligent vehicles vary widely, Blocks and files*. Available at: https://blocksandfiles.com/2020/01/17/connected-car-data-storage-estimates-vary-widely/.

[178] "5G Automotive Vision", European Commission, 5G PPP, ERTICO ITS Europe, October 20, 2015.

[179] Alberio, M., and Parladori G., 2017, *Innovation in automotive: A challenge for 5G and beyond network*, International Conference of Electrical and Electronic Technologies for Automotive, 2017, pp. 1-6

Autonomous driving functions and related 5G infrastructure could be targeted by cyberterrorists and criminals. The innovations driving these technologies transform cars into information clearinghouses. Cybersecurity researchers have shown in the last couple of years that hacking of connected cars should be a great concern. Hence, regulators began to set out minimum cybersecurity requirements for new vehicles[180].

These new regulations **will oblige the automotive OEMs to establish adequate cyber-risk management practices** in the development, production, and post-production of their products. This includes OTA updates and the possibility to correct security issues after a vehicle is sold. To be successful at cybersecurity, it is required to have new processes, new skills, and working practices along the value chain, like identifying cyber risks, designing secure hardware and software architectures, and developing and testing secure code and chips[181].

The issue of cybersecurity cannot be separated by the reliance on Chinese technology[182]. The potential benefits of 5G technology are large; hence, much can be gained from having a leadership position in the development. At the moment, China is the most considerable player in the global value chain of digital infrastructures and Chinese telecom provider Huawei has become the leading supplier of 5G equipment and infrastructure. In light of Huawei's strong position in the 5G technology domain and the recent debate surrounding network security, the EU has decided to pursue a common approach to cybersecurity (e.g. the EU toolbox on 5G cybersecurity), which also plays an important role in the autonomy of the EU, the control over data, the course of digital innovation, and the ability to create regulatory frameworks in the digital environment[183].

In Europe, both Ericsson and Nokia are successfully working on the 5G infrastructure. However, Huawei can outspend their combined R&D resources, and the company remains the most prominent supplier of 5G equipment and infrastructure[184]. Nevertheless, Huawei has also been an important partner in the past. For example, as a partner in the ERTICO partnership, which brings together public and private stakeholders across Europe to work on intelligent transport systems, or through the Horizon 2020 Autopilot project, to which Huawei contributes by providing and integrating an IoT platform.

3.2.2 Future mobility concepts

Finally, it is important to also take a look at the future of road transport, both in an urban and a rural environment. The way people and goods are transported is likely to change, both on the roads and for other transport modes. This will impact the automotive sector as it affects the demand for vehicles. The changes to transport paradigms are driven by automation, connectivity, decarbonisation and sharing.

Available at: https://www.semanticscholar.org/paper/Innovation-in-automotive%3A-A-challenge-for-5G-and-Alberio-Parladori/632a743bd58baf6b0e6047df42a83dc40b272aac.

180 UNECE, Proposal for a new UN Regulation on uniform provisions concerning the approval of vehicles with regard to cyber security and of their cybersecurity management systems; UNECE, Proposal for a new UN Regulation on uniform provisions concerning the approval of vehicles with regard to software update processes and of software update management systems.

181 McKinsey, 2020, Cybersecurity in automotive Mastering the challenge. Available at: https://www.mckinsey.com/~/media/mckinsey/industries/automotive%20and%20assembly/our%20insights/cybersecurity%20in%20automotive%20mastering%20the%20challenge/cybersecurity-in-automotive-mastering-the-challenge.pdf.

182 European Parliamentary Research Service, 2020, EPRS Ideas Paper Towards a more resilient EU: Digital sovereignty for Europe. European Parliament. Available at: https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/651992/EPRS_BRI(2020)651992_EN.pdf.

183 Ibid,

184 Rühlig, T., & Björk, M., 2020, What to Make of the Huawei Debate? 5G Network Security and Technology Dependency in Europe.

Due to the many different factors, we can envision different future scenarios, some favouring public transport and others favouring shared or private vehicles, as well as multimodal concepts.

Some less optimistic scenarios predict a future with increased reliance on private cars, which, while being electric, still congest roads and put pressure on urban traffic with empty AVs driving to pick up passengers. However, the **ambition with smart mobility is to move towards a more efficient and accessible transport system with reduced accidents, congestion and pollution**.

This will not be straightforward, as exemplified in the contentious debates around e-scooter sharing schemes. While these are certainly revolutionising mobility, their benefits have been called into question by reports on accidents, the cluttering of city spaces, and emissions in production, charging and (re)distribution[185]. The same might apply for car-sharing, ride-sharing and ride-hailing services, where early evidence also points to them not necessarily being more efficient[186]. In fact, in some scenarios, increased car traffic caused by more vehicles on the road (and potentially empty trips of AVs) could lead to increased congestion in urban areas and have high external costs on society. However, this depends also on the preparedness and the decisions of local authorities; for example, one interviewee pointed out that cities like Los Angeles put high demands on mobility providers and were able to take control of the mobility data generated.

In terms of **vehicle demand**, CAVs and shared mobility have diverging effects[187]:

- AVs or mobility as a service (MaaS) increases the availability of personal transport to the disabled, elderly or young people without a driving licence;
- Mobility concepts increasing vehicle occupancy, such as car-pooling and ride-hailing services, allow fewer vehicles to serve the same demand and, however, might also attract more users from other modes as they make using cars more affordable;
- Car sharing can reduce the total number of vehicles while keeping the number of vehicles on roads stable in order to satisfy mobility needs by improving vehicle utilization[188];
- In contrast, ride-hailing does not lead to decreased car ownership and can induce more journeys;
- Connectivity, in particular, promotes multimodality by allowing users to grasp the different transport opportunities through apps and online platforms more easily; and
- CAVs, with their increased comfort and travel experience, will possibly increase vehicle demand once prices fall enough and they are introduced to a mass market[189].

In conclusion, the impact of new mobility concepts on vehicle demand is unclear as it largely depends on policy choices affecting the availability of alternative modes, inclusiveness of CAV solutions and the cost associated with vehicle ownership and vehicle usage (compared to the available alternatives).

[185] A good discussion on the topic is provided in this article: Perry, F., 2020, *Why we have a love-hate relationship with electric scooters*, Future Planet.
Available at: https://www.bbc.com/future/article/20200608-how-sustainable-are-electric-scooters.

[186] Alonso Raposo, M., et al, 2019, *The future of road transport - Implications of automated, connected, low-carbon and shared mobility*, Joint Research Centre. Available at: https://publications.jrc.ec.europa.eu/repository/handle/JRC116644.

[187] Ibid.

[188] However, not owning a car combined with the availability of alternative modes of transport can also lead to a reduced amount of vehicles on the road as users might more carefully assess the available options.

[189] In general, our interviewees expected that CAVs will also be available to the mass market and not just as a premium segment as also volume brands as Toyota or Volkswagen are investing in this area. However, widespread deployment apart from specific use cases is not expected in the near future.

OEMs are already adapting to this new reality by also including new mobility services in their offer (see section 4.1), and the future success of the EU automotive sector will also depend on having the right environment to try out new mobility concepts for example, through living labs[190].

3.3 Conclusions and SWOT assessment

Concluding chapter 3, we perform a SWOT analysis to take stock of the main forces acting upon digitalisation in the EU automotive sector. Figure 3.4: SWOT Analysis of CAVs in Europe summarises our identified strengths, weaknesses, opportunities and threats.

Similar to the previous chapter on the greening of the automotive industry, **a key strength of Europe is its well-established automotive sector**. The EU boasts not only some of the largest OEMs with the VW Group, Daimler and Stellantis but also the largest automotive suppliers with Bosch, Continental and ZF Friedrichshafen. This well-developed value chain puts Europe in a position to leverage the existing know-how and use its resources to develop new capabilities in digital technologies.

Another strength is in the existing innovation capabilities of the EU automotive sector. Most of the innovations leading towards CAVs originate from European manufacturers. In addition, the extraordinary high R&D intensity of the EU automotive sector shows the ambition to stay ahead in the global innovation race. Finally, while covered more in detail in chapter 5, an important strength is also the foresight with which EU and many Member State regulators address future mobility focusing on topics such as operation and testing of AVs, liability concerns, access to data, data protection and more.

The **key weakness of the EU automotive sector in digital technologies is the lack of a strong ICT sector to complement it**. There are no large European digital players, which in other countries have shown to become increasingly important for CAV technologies. The EU automotive sector knows how to engineer a car, but it now needs to rethink this process and embed software into this process. EU companies have for now opted to either develop their own capabilities (alone or in joint venture) or to partner with these digital players from third countries.

A second weakness is a lack of venture capital and funding for the scale-up of start-ups. Europe has a strong ecosystem of automotive start-ups working in the fields of connectivity and autonomous driving; however, they do not have the same access to funding as their American and Chinese counterparts. In fact, often European start-ups are bought by large American technology companies. For example, the Italian company VisLab, one of the early AV pioneers, was acquired by Ambarella in 2015. This lack of funding can be a barrier to bringing new innovations to the European market.

In terms of opportunities, the dominance of European manufacturers on the EU market and access to world markets both in the USA and, to some extent, China gives the EU automotive sector an advantage in benefitting from these new technologies. In addition, as will be discussed further in chapter 5, the EU's political ambitions in the twin transition embedded in the recovery funding and EU research aspirations give the EU sector access to funding and political support to lead the digital transition.

This can be seen in the already record investments in Europe's semiconductor industry.

[190] For example, as is being done in the Netherlands with the attempt to promote the country as a living lab to develop and test new opportunities in the field of smart mobility. See: TNO, 2020, *Smart Mobility*. Available at: https://www.tno.nl/media/7613/magazine-smart-mobility.pdf.

There are, however, also various threats. Chief among them is the **threat of new entrants in the market and ensuing disruptions**. As discussed, traditional manufacturers and suppliers are challenged by large technology companies entering the market. Many of these are strategically better placed in succeeding in digital technologies and are considered top innovators in CAV technologies, while traditional suppliers heavily rely on vehicle production and engineering, areas from which less value-added will be generated in the future. This shift to ICT has led to the EU sector's leadership position in innovation shrinking.

Another threat is in the prevailing dependencies on key supporting industries such as semiconductors slowing down the production of new vehicles as well as the reliance on 5G infrastructure for proper connectivity. In addition, the lack of user acceptance and more traditional consumers in Europe might slow uptake compared to Chinese and US markets. Already predictions expect that the Chinese and American markets will grow faster for SAVs. Finally, the already existing lack of skilled labour is likely to grow with the increasing demand for software engineers and other technical skills.

Figure 3.4: SWOT Analysis of CAVs in Europe

STRENGTHS

- Established automotive manufacturer and supplier base with strong brand value, technological and financial capacities.
- Strong existing innovation capabilities in automotive and in CAV technologies combined with high R&D intensity and a start-up ecosystem.
- Large and integrated continental consumption market and access to global markets.
- Coherent long-term policy strategies at the European level.

WEAKNESSES

- Lack of a strong ICT sector and large European digital players impeding access to data, digital ecosystems and important connectivity technologies.
- Apart from largest OEMs lack of sufficient financial capabilities to stem the digital transition alone.
- Lack of venture capital and scale-up funding for start-ups cementing reliance on large OEMs and hindering growth of new innovative companies.
- Lack of digital and software engineering skills within the sector and the wider EU economy.

OPPORTUNITIES

- Established presence in the European and international markets.
- New digital services open up new business opportunities beyond vehicle sales.
- Political ambitions coupled with regulatory foresight giving the European sector strategic directions and funding opportunities.
- Characteristics of European urban and rural regions providing ample opportunities for new mobility concepts.

THREATS

- Increased competition from new entrants and technology companies.
- Interruptions to roll-out of supporting infrastructure (i.e. 5G networks) could slow the deployment of CAVs.
- Dependence on foreign key supporting industries (e.g. semi-conductors, technologies for 5G mobile communication standards)
- Lack of user acceptance and slow uptake of demand in Europe compared to other regions.
- Increased lack of digital skills could lead to an intensified global competition for talent.

4 NEW BUSINESS MODELS AND INDUSTRY RESILIENCE

KEY FINDINGS

- The EU automotive sector needs to be prepared to adapt its strategies and business models in order to be ready for a shift in revenue generation to digital services;
- To meet new customer needs, automotive OEMs are required to enter into digitally-enabled collaborations;
- The influence of tier 0.5 and tier-one suppliers in the technological forefront of the electrification and battery supply chain will increase significantly;
- Value creation is expected to shift from OEMs to suppliers as BEV penetration increases;
- Lead firms in the global value chain are more prone to diversify suppliers and near-shore production closer to demand;
- This provides opportunities for domestic SMEs with the technical and commercial knowledge to internationalise to gain better access to global value chains; and
- With increasing demand, competition for talent will intensify.

4.1 New connected and data-driven services

The new trends in technology will change the business models and value creation patterns of manufacturers in the automotive industry. The previously described shift to software and digital services, like connectivity and mobility services using in-vehicle data,[191] brings the opportunity for new services offered by manufacturers to car users. These new services could include navigation services, search services, entertainment, and insurance schemes, among others[192].

It is believed that these new digital services will contribute largely to value creation in the future. **Research from CAM expects that software-based digital services will generate an extra EUR 1000 per vehicle of potential revenue by 2030**[193]. The argument is based on the thought that, in the future, consumers in the automotive sector will not only buy vehicles but use a combined vehicle/software product, either in a private or shared usage model. Hence, according to PwC, the software-based interaction with the consumers of the future will lead to higher revenues[194].

These new digital services require the provider to have access to in-vehicle data to be able to enter the market for aftermarket and complimentary services. OEMs do usually not own these

[191] CAM (2021). Innovation dynamics and success factors in the automotive industry An analysis of the future trends in the fields of connectivity, autonomous driving and mobility services.

[192] Kerber, W., 2019, Data Governance in Connected Cars: The Problem of Access to In-Vehicle Data, JIPITEC 310. Available at: https://www.jipitec.eu/issues/jipitec-9-3-2018/4807.

[193] For the VW Group, this could generate an amount to EUR 5-8 billion per year. While, Mercedes Benz could increase the sales volume to EUR 2.5 billion in the German market and a rough EUR 22 billion worldwide in 2030. Source: CAM, 2021.

[194] PwC, 2018, *Five trends transforming the Automotive Industry*.
Available at: https://www.pwc.com/gx/en/industries/automotive/assets/pwc-five-trends-transforming-the-automotive-industry.pdf.

complex technologies in-house. Therefore, car manufactures are challenged by technology companies like Alphabet, Apple, or Amazon.

This threat is reflected by the rising market capitalisation of these companies, while the market capitalisation of traditional manufacturers has stagnated over the last five years.

The problem is the asymmetry of competencies in innovation technologies between the OEMs and the large digital companies (see section 3.1.1). OEMs have to either change their business plan towards digital services or will depend in the future on collaborations with third companies[195]. Similarly, PwC argues that manufacturers who solely focus on the production of hardware will find it difficult to manage the change in the automotive sector. Business models that include software services could lead to new sources of income; however, they could also threaten the core business of the OEMs (i.e. the production and sale of cars). In order to be successful, it is argued that **OEMs need to be able to provide complete packages combining hardware (e.g. vehicles) with software and associated services**[196].

Automotive companies slow to adapt to the new realities of the digital world are said to be quickly outmatched by companies willing and able to make a substantial investment to transform their business and enter these new markets[197]. In line with section 3.1.1, this provides a possibility for technology companies and newcomers to establish themselves in the market.

Box 4.1: Adapting business models in practice

The example of VW Group and BMW Group

European OEMs are recognising the value of digital services. For example, currently, only 10% of the entire software in the vehicle is owned by Volkswagen. However, to ensure a larger market share in the future, Volkswagen wants to invest in vehicle architecture. The company plans to develop an overarching operating system and software stack. They plan to have 60% of the vehicle software owned by Volkswagen. The new software strategy of Volkswagen would create greater consumer benefits, like over-the-air updates and reduce maintenance time. Meanwhile, it also should reduce complexity costs for Volkswagen, including lower material and development costs.

BMW has already developed its own operating system, which allows for over-the-air updates. After Tesla, BMW is leading in this area and uses these updates, among others, for information and entertainment applications. For example, BMW is using a gamification application with BMW Points. With this programme, the company integrates in-house technology competence in electromobility and digitalisation to incentivise purely electric driving. The BMW Group already provides this service in the Netherlands, Belgium, and Germany, and wants to expand it in the course of 2021.

Sources: Center of Automotive Management (CAM). (2021). Innovation dynamics and success factors in the automotive industry An analysis of the future trends in the fields of connectivity, autonomous driving and mobility services; AND BMW Group. (15 October 2020). Drive electric, collect BMW Points, charge for free: BMW presents the worldwide first bonus programme for Plug-in Hybrid Model drivers. [Press release].

[195] Center of Automotive Management (CAM). (2021, January). Innovation dynamics and success factors in the automotive industry *An analysis of the future trends in the fields of connectivity, autonomous driving and mobility services.*

[196] PwC, 2018, Five trends transforming the Automotive Industry.
Available at: https://www.pwc.com/gx/en/industries/automotive/assets/pwc-five-trends-transforming-the-automotive-industry.pdf.

[197] Oliver Wyman, 2017, Digital OEM #3. Digital Business Models For Automakers.
Available at:
https://www.oliverwyman.com/content/dam/oliverwyman/v2/publications/2017/sep/20170921_Oliver_Wyman_Digital_OEM_Business_Models_Web_final.pdf.

4.2 Understanding the bargaining power between OEMs and Suppliers

Most future scenarios of how the future automotive sector would look like demand a significant willingness to change on the part of the automotive OEMs[198]. Questions are increasing as to how OEMs can sustain their competitiveness against a backdrop of major 'cash-rich' technology players seeking to transition into automotive, the advances in software competencies outside the sector, the pace of re-skilling required and the interdependencies at play in terms of charging and hydrogen fuel cell refilling infrastructure.

Out of four scenarios envisaged by Deloitte[199], two caution that increasingly OEMs may not be able to fully cash in on their total revenue potential due to the decreasing margins per vehicle, and that traditional brand value will diminish. Such manifestation **would profoundly undermine OEM influence and bargaining position vis-à-vis suppliers**. Especially given the existing trend where tier-one companies, for example, are already becoming 'fab-less' in terms of designing semiconductors for fabrication in the main foundries in Taiwan. An exception is the Bosch wafer plant in Dresden, which has the potential to boost supply chain resilience for some European clients.

'Over the next 10 to 15 years, the market structure will shift as suppliers, ride-hailing companies, tech giants along with cities and larger mobility ecosystems seek to gain influence at the expense of OEMs[200]'. BCG also estimates that the new profit pools emerging, which include BEVs, components for BEVs and autonomous vehicles, data and connectivity services, will account for 40% of industry profits in 2035 (1% in 2017).

OEMs are likely to be squeezed from two directions. First, automotive OEMs expecting to benefit from meeting new customer needs with digitally enabled collaborations will find that the sheer volume of partners needed will diminish profits. Most successful digital ecosystems have about 40 partners. Second, value creation is expected to shift from OEMs to suppliers as BEV penetration increases. OEMs value share, which is their share of the costs of components manufactured per vehicle, is expected to fall to between 10% and 20% for BEVs by 2030. This is considerably less than the current value share of 27% from ICE-powered vehicles. OEMs also face a double-edged sword in terms of the need to invest in growth areas at the same time that margins in the core business are declining.

OEMs should not be complacent and think their current strong brand will simply retain brand value over the next decade. Consumer attitudes, priorities, and preferences are already fundamentally shifting to the point that 'automotive heritage and history no longer mean much to many people[201]'. Once again, a combination of research sources and interviews conclude that the influence and bargaining power of the OEMs are more likely to diminish than strengthen over the next decade, albeit most of the OEMs would not agree with this view. Essentially, change is and will continue to impact the entire automotive value chain, as illustrated in Figure 4.1.

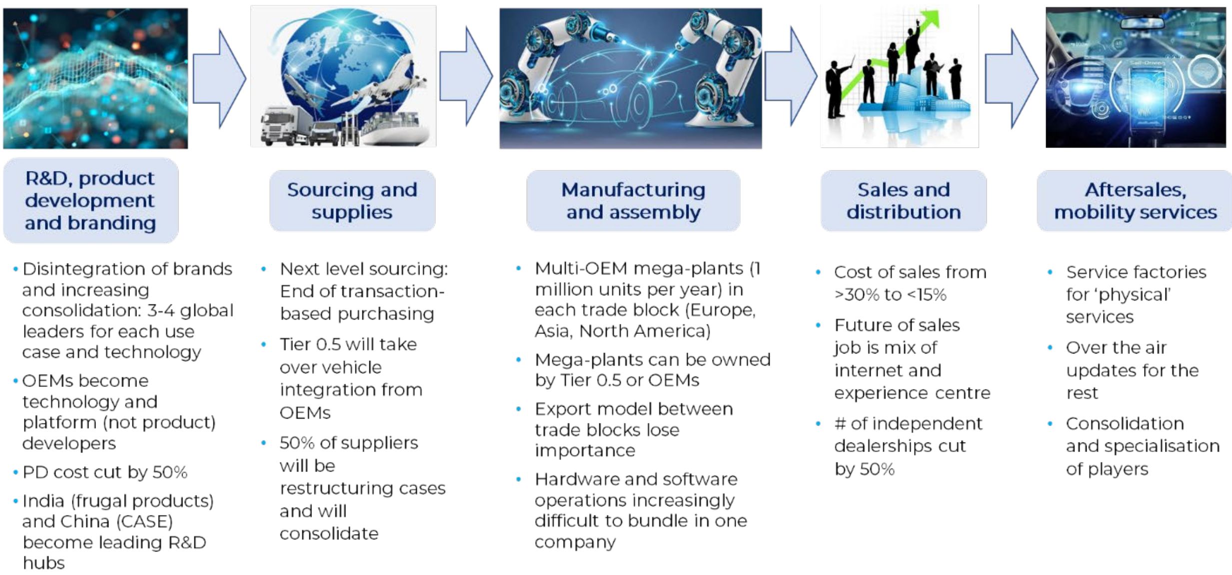
[198] Deloitte. (2017). The Future of the Automotive Value Chain - 2025 and Beyond. Available at: https://www2.deloitte.com/content/dam/Deloitte/us/Documents/consumer-business/us-auto-the-future-of-the-automotive-value-chain.pdf.

[199] Ibid.

[200] Lang. N., 2019, *A profitability roadmap for the fast-charging automotive sector*, Boston Consulting Group / World Economic Forum. Available at: https://www.weforum.org/agenda/2019/08/how-to-drive-growth-in-a-fast-changing-automotive-sector/.

[201] Oliver Wyman, 2019, *Building the Automotive Industry of 2030*. Available at: https://www.oliverwyman.com/our-expertise/insights/2019/jun/automotive-manager-2019/cover-story/building-the-automotive-industry-of-2030.html.

Figure 4.1: Changes in the automotive industry will affect the whole value chain



Source: Oliver and Wyman 2019 – Slightly adapted by Ecorys 2021.

When it comes to OEMs developing the semiconductors for the different capability levels of autonomous driving from ADAS to AVs, we detected a distinct fork in the road from our interviews and research. **Many OEMs have begun designing chips in-house, while others do not classify semiconductor design as a core business and thus will continue to outsource.**
Given the greening and digitalization challenge the automotive industry is facing, we believe that it is in the best interest of OEMs in Europe to become fab-less and design semiconductors in-house. The Electronic Times[202] reported that several OEMs and first-tier suppliers like Magna have already gone fabless whereby they design their own semiconductors, which are principally fabricated, assembled and tested in the Asia Pacific region.
Currently, according to McKinsey[203], customised chips for EVs / autonomous vehicles are only available from a few semiconductor companies, and thus more OEMs are designing them in-house to reduce development timelines and gain more control.

This design expertise can optimise performance for specific algorithms and shorten development times. Furthermore, in-house chip design also affords the OEMs more scope to create customised solutions that could differentiate their connectivity and autonomous driving[204]. If the OEMs do not fill this space, the tier 0.5 and tier 1 suppliers will gain more ground in semiconductor design, thereby diminishing OEM influence.

In conclusion, the influence of tier 0.5 and tier-one suppliers in the technological forefront of the electrification and battery supply chain will increase significantly while suppliers overly dependent on ICE powertrains will not only find the gap in influence with the OEMs widening, as EV powertrains have fewer components, many existing European suppliers may be threatened or even eliminated.

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[202] EE Times, 2021, Automakers Will Go Fabless.
[203] McKinsey, 2021, Automotive semiconductors for the autonomous age.
[204] McKinsey & Company, 2021, *Automotive semiconductors for the autonomous age*. Available at: https://www.mckinsey.com/industries/advanced-electronics/our-insights/automotive-semiconductors-for-the-autonomous-age.

4.3 Opportunities for domestic SMEs to integrate with automotive GVCs

The automotive industry will remain highly concentrated, with a few countries leading world production. **However, a key issue is to understand and anticipate the future role of the multinational corporations (MNCs),** which are at the heart of most GVCs, including automotive. Pre-COVID-19, the primary impetus for GVC expansion over the past three decades was derived from the MNCs themselves, which were enabled by dramatically reduced communication and trade costs[205]. Consequently, operations were moved to the global arena through production fragmentation, offshoring and outsourcing.

Early indications are that hyper-globalisation has peaked, reflected in the downward trend in FDI flows in recent years. A review by K4D[206] concludes that **lead firms in GVCs were now more prone to diversify suppliers and near-shore production closer to demand**. This can already be witnessed through the dramatic increase in EV battery production in the EU on the one hand, and the intensification of linkages with existing suppliers, on the other. The main examples are in Central and Eastern Europe, while Morocco will also witness a major increase in EV and EV component production. While the strategies embraced by the OEMs along with tier one suppliers depend on the complexity of the automotive segment, the overarching aim is to increase the resilience of the GVC to which end digitalisation is an essential tool. This, in turn, means that the digitalisation competencies of the SMEs themselves become a prerequisite for entry to the pathways leading to automotive GVC integration.

a. Four Main Pathways

EU domestic firms internationalise and thus participate in the automotive GVCs through four main pathways:

- Supplier linkages in GVC networks;
- Strategic alliances with MNCs;
- Direct exporting;
- Outward FDI.

According to Qiang[207], supplier linkages depend on the preference of international partners with both the willingness and commitment to source local inputs on the basis that the domestic firm can meet cost, quality, and timing parameters. Strategic alliances rely on the complementary capacities and market knowledge of a domestic firm and an MNC. Within this scenario, it is particularly beneficial if the EU Member State has been successful in attracting FDI.

Direct exporting can be challenging for domestic SMEs, given that they must have the minimum production capabilities and overseas market knowledge to compete internationally. The fourth pathway of outward FDI tends to be more demanding for domestic SMEs in terms of economies of scale and financial solvency requirements to invest in other countries along the automotive GVC. However, the more innovative and digitally attuned the SME, the easier it becomes to enter into joint ventures or possibly to serve international markets more directly.

[205] Qiang, C., Liu, Y., Steenbergen, V., 2021, *An Investment Perspective on Global Value Chains*. World Bank Group. Available at: https://openknowledge.worldbank.org/handle/10986/35526.

[206] Quak, E., 2020, *The Covid-19 pandemic and the future of Global Value Chains*. Institute of Development Studies. Available at: https://opendocs.ids.ac.uk/opendocs/handle/20.500.12413/15668.

[207] Qiang, C., Liu, Y., Steenbergen, V., 2021, *An Investment Perspective on Global Value Chains*. World Bank Group. Available at: https://openknowledge.worldbank.org/handle/10986/35526.

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In practice, these pathways are not mutually exclusive and can build on each other to help domestic SMEs gain the technical and commercial knowledge to internationalise. Firms that are successful in the first pathway also become increasingly likely to extend their involvement in other global production networks[208]. There is, therefore, considerable merit in developing the next generation of supplier linkages programmes by building on the successful supplier linkages interventions already initiated and implemented by member states.

b. Supplier Linkages Development

In recent years the **World Bank Group has initiated automotive supplier development programmes in several countries**, partially modelled on the Czech Supplier development programme in automotive and electronics which was funded by the EU pre-accession PHARE Programme. As of Q3 2021, CzechInvest's (the Investment and Business Development Agency of the Czech Republic) supplier database comprised over 4,000 companies, of which most were SMEs, and one quarter were automotive suppliers. While the initiative was first piloted two decades ago, there were several very pertinent lessons to be learnt and applied from supplier development which are just as relevant now as they were then. Those key 'take-aways' have been summarised below.

[208] Alcacer, J and J. Oxley, 2014, *Learning by Supplying*. Strategic Management Journal 35 (2): 204-23. Available at: https://onlinelibrary.wiley.com/doi/abs/10.1002/smj.2134.

Box 4.2: Case Study - Czech Automotive SME Supplier Development Programme

Methodology - Czech Automotive SME Supplier Development Programme

- The supplier development programme (SDP) was demand driven by the MNCs but with the main aim of benefiting domestic SMEs.
- A dozen MNCs were involved throughout the project, and 45 SMEs (after various screening filters were applied to circa 200 local suppliers) received targeted training based on needs uncovered during a series of business reviews.
- The reviews were based on the European Foundation for Quality Management (EFQM) model and looked at the totality of the business.
- In addition to focusing on the areas of performance of most importance to meeting MNC requirements, the aim was to get participation/buy-in from domestic company management and convince them of the value of the process, which meant a major commitment of management time if it was to be worthwhile.
- The direct commitment by the MNCs was, in and of itself, a major incentive for domestic SMEs to participate.
- A twin-track approach was adopted with domestic company management carrying out a self-assessment using a simplified version of the EFQM in parallel with a more in-depth review of external assessors.
- An evaluation of the 18-month pilot found that 15 of the SMEs gained new business with contracts worth EUR 45 million, while four companies found new customers abroad and a further three SMEs secured incremental contracts but for higher value-added content.

Lessons Learned

1. Three of the key factors for success - a) Government leadership is essential; b) the programme is demand-driven - by the MNCs; c) the public sector must develop and enable an agency to manage the programme.
2. High-level political and industrial ownership of the programme is essential to maximize impact.
3. Participating MNCs were actively involved in programme development and implementation, playing a key role in mapping potential suppliers and identifying skill gaps.
4. The focus on supplier companies was based far more on the basis of potential and not need.
5. Review process anchored by comprehensive supplier quality audits based on the EFQM benchmarking tool.
6. Provision of hands-on practical mentoring support to help companies help themselves by improving company performance in line with the EFQM reviews.

Source: Pilot Czech Supplier Development Programme in Automotive and Electronics (2010) World Bank Group.

4.4 Competition for talent

The automotive sector needs to build up new skills to accommodate the move towards digitally-driven services and products as well as the green transition towards EVs and potentially HFCs described in chapter 2. **Combined with increasing global competition, this may lead to competition to secure the right talent for the sector**. While the overall labour demand is expected to decrease due to automation and potentially due to the shift from ICE to electric engines (see the debate in section 0), there will be increased competition for highly skilled labour in software, electrical engineering, battery chemistry and related areas. In addition, competition for talent also comes from technology companies that are entering the automotive market209 as well as other industries (e.g. aerospace engineering). Adding to this is, are the existing labour shortage for digital skills and the generational changes described in section 3.1.2.

Shortages of skilled labour are not a purely EU phenomenon; also, sources from China[210], the USA[211] and the UK[212] discuss the scarcity of talent in the sector as an existing bottleneck for growth. This technology-driven paradigm shift towards sustainable mobility and from hardware to software requires automotive companies to improve global talent management, attracting talent internationally.[213] In addition, it requires policymakers to adapt education systems and increase the popularity of education in STEM fields.

CAVs and IoT for industry 4.0 all demand a digital proficiency that few industry players currently possess. Combined with a lack of comprehensive digital strategies for addressing the "connected life" needs of their customers, even as a range of tech-savvy newcomers encroach on car manufacturers' traditional territory. In our interviews, there were mixed opinions. Some interviewees said that the sector is overall an attractive employer known for its good working conditions and having the advantage that employees see the tangible results of their work on the streets (unlike pure software-driven companies). Others were more pessimistic, arguing that the sector needs to increase its attractiveness by, for example, providing more flexible work arrangements.

The EU and the sector are already reacting to this with projects such as DRIVES, the Automotive Skill Alliance and the recently launched Pact for Skills for automotive (see section 5.3.2). In addition, as part of the Coordinated Plan on AI, there were talks for exchange of best practices on the "Blue card", EU visa for talents, and the European Commission presented the possibility of promoting partnerships between companies and training institutions, for example by offering PhD and post-docs in cooperation with industries to train and retain talents.

209 Oliver Wyman, 2015, *Help Wanted: Automotive Suppliers And The Talent Challenge*. Available at: https://www.oliverwyman.com/content/dam/oliver-wyman/global/en/2015/jul/Oliver-Wyman-26-29-Automotive-Manager-2015-Help-wanted.pdf.

210 Mao, G. and Hu B. Exploring talent flow in Wuhan automotive industry cluster at China, *International Journal of Production Economics, Volume* 122, Issue 1, 2009, 395-402, Available at: https://doi.org/10.1016/j.ijpe.2009.06.008.

211 McKinsey & Company, 2020, *Winning the race for talent: A road map for the automotive industry*. Available at: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/winning-the-race-for-talent-a-road-map-for-the-automotive-industry.

212 Autocar, 2021, *Talent wanted: Drivers of Change competition opens for entries*. Available at: https://www.autocar.co.uk/car-news/industry-news-tech%2C-development-and-manufacturing/talent-wanted-drivers-change-competition.

213 Eliasson Wilsgard, T. and Walker, A., 2017, *Talent Identification and Talent Selection of International Software Competencies within Multinational Automotive Corporation.* Available at: http://hdl.handle.net/2077/53140.

5. EU LEVEL POLICY RESPONSES

In the past years, the EU has been active in paving the way for the twin transition of EU industries and society at large. Various initiatives have been rolled out to support the goal of greening the economy and maintaining leadership in a digital world. The nature and scale of such transition are unprecedented, as reflected in Commission President von der Leyen's Political Guidelines[214], the priorities set out by the European Parliament and the European Council's Strategic Agenda 2019-2024[215]. These existing trends have been accelerated by the COVID-19 pandemic, pushing industries and policy-makers to react more drastically.

On 10 March 2020, the European Commission presented the **EU industrial strategy of 2020**[216], aimed at supporting the twin transition to a greener and digital economy, making EU industries more competitive globally, and enhance the strategic autonomy of Europe. The strategy recognises that the twin transition will affect every part of the economy and society, requiring new investments, technologies, and business models. This is especially necessary to preserve the industrial leading role and EU's competitiveness in a changing world.

Automotive is placed at the heart of both transitions, and it has the potential to drive them. This is the case as the industry is focusing both on alternative fuels and smart and connected mobility. The sector's entire value chain must help shape new international standards for safe, sustainable, accessible, secure and resilient mobility.

As the industrial strategy was released a day before COVID-19 was declared a pandemic by WHO[217], on 05 May 2021, the Commission released a Communication on **Updating the 2020 New Industrial Strategy**[218]. The main reason for the update is to include the lesson learned during the pandemic. One of the main innovations proposed in the Communication is the definition of 14 industrial ecosystems, which includes mobility-transport-automotive, and the ambition to co-create in partnership with industry, public authorities, social partners and other stakeholders transition pathways for each of the ecosystems[219].

[214] Von der Leyen, U., 2019, *A Union that strives for more. My agenda for Europe* European Commission. Available at: https://ec.europa.eu/info/sites/default/files/political-guidelines-next-commission_en_0.pdf.

[215] European Council, 2019, *A new strategic agenda for the EU 2019-2024*. Available at: https://www.consilium.europa.eu/en/eu-strategic-agenda-2019-2024/.

[216] European Commission, 2020, *A New Industrial Strategy for Europe*. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0102&from=EN.

[217] World Health Organization, 2020, *WHO Director-General's opening remarks at the media briefing on COVID-19 - 11 March 2020*. Available at: https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020.

[218] European Commission, 2021, *Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe's recovery*. Available at: https://ec.europa.eu/info/sites/default/files/communication-new-industrial-strategy.pdf.

[219] European Commission, 2021, *Annual single market report 2021*. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021SC0351&from=en.

5.1 Greening the economy

The **European Green Deal**[220] announced on 11 December 2019 and subsequently endorsed by the European Parliament and Member States, sets out a detailed vision to make Europe the first climate-neutral continent by 2050, establish a circular economy and eliminate pollution, while boosting the competitiveness of European industry and ensuring a just transition for the regions and workers affected. In the industrial strategy, the Commission notes that in order to reduce carbon footprints and accelerate the transition, access to clean technologies, energy, and raw material is key. Stepping up investment in research, innovation, deployment and up-to-date infrastructure will help develop new production processes and create jobs in the process.

The Commission presented its **Circular Economy Action Plan**[221] on 11 March 2020, with the ambition of decoupling economic growth from resource use, reducing consumption footprint and doubling circular material use rate in the coming decades. Batteries and vehicles are among the key value chains selected to increase sectoral actions aimed at expanding the market for circular products. The plan sets a priority for different EU actions aimed at updating rules to increase the sustainability and transparency requirements for batteries, including the revision of rules on **end-of-life vehicles**[222]. The goal is to promote more circular business models, linking design issues to end-of-life treatments, improving safe and environmentally sound production, recollection, dismantling and disposal of end-of-life vehicles.

In order to put EU industries in a position of frontrunner in key technologies, the Commission refers in the industrial strategy to **Industrial Alliances** as successful strategies to develop EU leadership. Alliances can help finance large-scale projects with positive spill-over effects across Europe, using the knowledge of SMEs, big companies, researchers and regions to help remove barriers to innovation and improve policy coherence.[223] A good example of a successful industrial alliance is the **European Battery Alliance**[224]. In 2018, the Commission also released a **strategic action plan for batteries**[225]. The action plan has six priority areas: securing access to raw material, supporting EU battery cell manufacturing, strengthen R&I programmes, securing a highly skilled workforce, supporting sustainable EU battery cell manufacturing, and ensuring consistency with broader EU frameworks.

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[220] European Commission, 2019, *The European Green Deal.*, Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2019%3A640%3AFIN.

[221] European Commission, 2020, *Circular Economy Action Plan for a cleaner and more competitive Europe*. Available at: https://ec.europa.eu/environment/pdf/circular-economy/new_circular_economy_action_plan.pdf.

[222] The revision of the ELV Directive sets targets based on the weight of a vehicle (minimum of 95% for reuse and recovery; 85% for reuse and recycling) with European automotive manufacturers being responsible for disposal/recycling costs. It also imposes provisions on vehicle design (e.g. use of chemicals). See: European commission, 2021, *End-of-Life Vehicles*. Available at: https://ec.europa.eu/environment/topics/waste-and-recycling/end-life-vehicles_en.

[223] European Commission, 2020, *A New Industrial Strategy for Europe*. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0102&from=EN.

[224] The European Battery Alliance was launched in October 2017 in order to establish a complete domestic battery value chain, which is seen as key for both a clean energy transition and a competitive industry. More than 400 industrial and innovation actors have already joined the alliance. More information are available at: European Commission, 2021, *European Battery Alliance*. Available at: https://ec.europa.eu/growth/industry/policy/european-battery-alliance_en.

[225] Annex to the Communication Europe on the move, available at: European Commission, 2018, *Europe on the move*. Available at: https://eur-lex.europa.eu/resource.html?uri=cellar:0e8b694e-59b5-11e8-ab41-01aa75ed71a1.0003.02/DOC_3&format=PDF. For an overview see: European Parliament, 2021, *New EU regulatory framework for batteries*. Available at: https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/689337/EPRS_BRI(2021)689337_EN.pdf.

Between the alliance and the EU's action plan, **Europe managed to become a leading investment destination in battery technology** (see section 2.1.4). In 2018, the EU had only about 3% of the global production capacity of Li-ion battery cells, while China had about 66% and South Korea, together with Japan and other Asian countries, about 20%. The ambition in the EU is to have 15 gigafactories in Europe, offering enough battery cells by 2025 to power six million electric cars (around 360 GWh). Based on the Transport & Environment (T&E) monitoring of current battery production intentions, the EU could be around 100 GWh above this target if the planned gigafactories are completed on schedule.

Batteries for electric vehicles are also a key research area that currently attracts a number of projects with significant EU funding[226].

Following the success of the EU Battery Alliance, in March 2020, the Commission announced the **European Clean Hydrogen Alliance**[227]. The Alliance aims at the deployment of hydrogen technologies by 2030, bringing together renewable and low-carbon hydrogen production, demand in industry, mobility and other sectors, and hydrogen transmission and distribution. It is part of efforts to accelerate the decarbonisation of industry and maintain industry leadership in Europe. The alliance will play an important role in facilitating and implementing the actions of the **European hydrogen strategy**[228] and, in particular, its investment agenda. Research and industrial innovation in hydrogen applications is an EU priority and receives substantial EU funding through the research framework programmes. Hydrogen projects are managed by the Fuel Cells and Hydrogen Joint Undertaking (FCH JU)[229], a public-private partnership supported by the European Commission[230].

On 9 December 2020, the Commission presented the **Strategy for Sustainable and Smart Mobility**[231], outlining the planned steps to transform the EU transport system. In order to meet the goals of the Green Deal, the transport sector must reduce emissions by 90% by 2050. The mobility strategy is coupled with an **action plan**[232] that includes 82 initiatives in 10 key areas for action with concrete measures to be adopted over the next four years. The strategy follows three main approaches:

- Reduce the dependence on fossil fuels by replacing existing fleets with low and zero-emission vehicles, also increasing the use of renewable fuels;
- Shift 75% of inland freight carried by road onto rails and waterways; and
- Internalise external costs.

As measurable milestones, the strategy aims to have in Europe **30 million zero-emission cars on the road and large-scale deployment automated mobility by 2030**. However, European automobile manufacturers (ACEA) argued that this target does not correspond with reality, and it would also

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226 European Commission, 2021, *SWD on Strategic dependencies and capacities, SWD(2021) 352*. Available at: https://ec.europa.eu/info/sites/default/files/strategic-dependencies-capacities.pdf.

227 See for more information the official website of the Alliance: https://www.ech2a.eu/.

228 Information on the strategy are available at: European Commission, 2021, *European Clean Hydrogen Alliance*. Available at: https://ec.europa.eu/growth/industry/policy/european-clean-hydrogen-alliance_en.

229 More information available at: https://www.fch.europa.eu/. The second phase of the FCH JU (2014-2024) is expected to benefit from EUR 665 million in EU support, which, complemented by private funding, will bring investments to a total of over EUR 1.3 billion.

230 For more information on the EU hydrogen policy, see: European Parliamentary Research Service, 2021, *EU Hydrogen policy*, European Parliament.
Available at: https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/689332/EPRS_BRI(2021)689332_EN.pdf.

231 European Commission, 2020, *Sustainable and Smart Mobility Strategy*.
Available at: https://ec.europa.eu/transport/sites/transport/files/legislation/com20200789.pdf.

232 European Commission, 2020, *Annex to the Sustainable and Smart Mobility Strategy*.
Available at: https://ec.europa.eu/transport/sites/transport/files/legislation/com20200789-annex.pdf.

require a more ambitious rollout of charging infrastructure[233]. By 2050, the Commission expects that in the EU, nearly all cars, vans, buses and new trucks are to be zero-emission. With regard to the automotive sector, the strategy wants to further tighten the CO2 emission standards for cars and vans as well as for trucks and buses. Stricter air pollutant emission standards (Euro 7) for combustion engine vehicles are to be introduced.

The road transport industry (IRU) cautioned that the strategy risks destroying the coach transport sector, which they see as by far the greenest and most inclusive form of transport. In their view, fuel alternatives to diesel are needed in the coming decades[234].

The sustainable and smart mobility strategy also proposes to review the **Alternative Fuels Infrastructure Directive**[235] and boost the availability of electricity and hydrogen by putting in place more vehicle-charging points. The European Alternative Fuels Observatory measures the progress in deploying infrastructure. It shows fast progress in EV charging infrastructure, however a comparatively slow one for hydrogen. In addition, for both, the infrastructure development is concentrated in a few Member States[236]. The measures designed to stimulate the demand for zero-emission vehicles include not only carbon pricing, taxation, road charging and changes to the rules on weights and dimensions but also actions supporting the uptake of these vehicles in corporate and urban fleets[237].

As part of the European Green Deal and the EU climate law[238], the Commission presented a package of 13 legislative proposals on 14 July 2021, under the name of '**Fit for 55' package**. The overarching goal of these proposals is to accomplish a reduction of greenhouse gas emissions of at least 55% by 2030. Similar to previous emission targets (see section 2.1.1), it is hoped that this can push the automotive sector to become more sustainable. However, ACEA already expressed its concerns and "urged all EU institutions to focus on innovation rather than mandating, or effectively banning, a specific technology". The sector argues that technology restrictions should be avoided, and all options (incl. ICE, PHEVs, BEVs and HFCs) need to play a role in the transition. In addition, commitments from all stakeholders are needed with binding targets for the deployment of charging and refuelling infrastructure [239].

Among the various proposals, those of direct relevance for the automotive sector are:

- **Stronger CO2 emission standards for cars and vans**[240]. The proposed amendments to the regulation setting CO2 emission standards for vehicles are expected to accelerate the transition

[233] European Parliamentary Research Service, 2021, *Sustainable and smart mobility strategy*, European Parliament. Available at: https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/659455/EPRS_BRI(2021)659455_EN.pdf.

[234] Ibid.

[235] For an overview, see: European Parliamentary Research Service, 2020, *Towards a revision of the Alternative Fuels Infrastructure Directive*, European Parliament. Available at: https://www.europarl.europa.eu/thinktank/en/document.html?reference=EPRS_BRI(2020)652011.

[236] For an overview, see European Alternative Fuels Observatory: https://www.eafo.eu/.

[237] See the annex to the strategy for the complete list of actions.

[238] Which enshrines in binding legislation the EU's commitments to climate neutrality and the target of reducing greenhouse emission by at least 55% BY 2030. European Commission, 2021, *European Climate Law*. Available at: https://ec.europa.eu/clima/policies/eu-climate-action/law_en.

[239] ACEA, 2021, *Fit for 55: EU auto industry's initial reaction to Europe's climate plans*. Available at: https://www.acea.auto/press-release/fit-for-55-eu-auto-industry-initial-reaction-to-europe-climate-plans/.

[240] European Commission, 2021, Regulation of the European Parliament and the Council amending Regulation (EU) 2019/631 1 as regards strengthening the CO2 emission performance standards for new passenger cars and new light commercial vehicles in line with the Union's increased climate ambition.

to zero-emission mobility by requiring average emissions of new cars to come down by 55% from 2030 and 100% from 2035 compared to 2021 levels. With this timeframe - and considering that the average lifespan of a car is around 15 years - the full conversion of the European car fleet would take place between 2035 and 2050; and

- **The proposed revision of the Directive on the deployment of alternative fuels infrastructure to ensure the reliability across Europe of cars with zero-emission.**[241] Under the proposed revision, Member States will be required to install charging and fuelling points at regular intervals on major highways: every 60 kilometres for electric charging and every 150 kilometres for hydrogen refuelling on major highways.

5.2 Digital transformation

The industrial strategy clearly recognised that scalability is key in a digitalised economy and maintained that Europe's twin transition would be supported by the strengthening of the internal market. To do so, the EU needs to speed up investment in R&D and the deployment of technologies in areas such as AI and data analytics, which are key for connected and autonomous vehicles, among others. This must be accompanied by further development of its critical digital infrastructures, such as the successful roll-out of highly secured and state-of-the-art 5G network as set out in the 2016 **5G Action Plan**[242], which will be a major enabler for future digital services and be at the heart of the industrial data wave. In this respect, the automotive sector joined forces to create the **5G Automotive Alliance**[243].

On 17 May 2018, the Commission proposed a **strategy for automated and connected mobility systems**[244]. The strategy sets out a common vision on automated mobility and identifies supporting actions for developing and deploying key technologies, services and infrastructure. Its goal is to ensure that the EU policy framework is up to date to support the deployment of connected and automated vehicles while addressing the concerns that will be key to strengthen public acceptance. The strategy was adopted as part of the **Third Mobility Package**[245].

The Strategy for **Sustainable and Smart Mobility**[246] of December 2020, which outlines the planned steps to transform the EU transport system, also focuses on digital aspects. Its **action plan**[247] includes two key areas of smart transformation – making connected and automated multimodal mobility reality

Available at: https://ec.europa.eu/info/sites/default/files/amendment-regulation-co2-emission-standards-cars-vans-with-annexes_en.pdf.

241 European Commission, 2021, Regulation of the European Parliament and the Council on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU of the European Parliament and of the Council. Available at: https://ec.europa.eu/info/sites/default/files/revision_of_the_directive_on_deployment_of_the_alternative_fuels_infrastructure_with_annex_0.pdf.

242 See for details: European Commission, *Europe's 5G Action Plan*.
Available at: https://digital-strategy.ec.europa.eu/en/library/europes-5g-action-plan.

243 See for details: 5G Automotive Association, 2021, *Bridging the automotive and ICT industries*.
Available at: https://5gaa.org/about-5gaa/about-us/.

244 European Commission, 2018, *On the road to automated mobility: An EU strategy for mobility of the future*. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1527002536861&uri=CELEX:52018DC0283.

245 European Commission, 2018, *Europe on the move*.
Available at: https://eur-lex.europa.eu/resource.html?uri=cellar:0e8b694e-59b5-11e8-ab41-01aa75ed71a1.0003.02/DOC_3&format=PDF.

246 European Commission, 2020, *Sustainable and Smart Mobility Strategy*.
Available at: https://ec.europa.eu/transport/sites/transport/files/legislation/com20200789.pdf.

247 European Commission, 2020, *Annex to the Sustainable and Smart Mobility Strategy*.
Available at: https://ec.europa.eu/transport/sites/transport/files/legislation/com20200789-annex.pdf.

and innovation, data and AI for smart mobility – with 19 specific actions. The EU must seize the opportunities presented by connected, cooperative, and automated mobility (CCAM). CCAM can provide mobility for all while improving road safety and efficiency.

The **European partnership on CCAM**[248] was developed under Horizon Europe in order to implement a shared, coherent and long-term European research and innovation agenda by bringing together actors from the entire value chain.

Furthermore, the digital transformation of the automotive sector requires further efforts related to data availability, access and exchange. For such purpose, the Commission will pave the way to establish a **European Common Mobility Data Space**. It will take into consideration the horizontal governance set out in the **Data Strategy**[249] of February 2020, the upcoming **Data Act**[250] and the principle of technology neutrality. Access to and sharing of vehicle and transport infrastructure data was highlighted as a key issue in the future competitiveness of the EU automotive sector by one interviewee. In fact, the **TN-ITS** and the **DATEX II**[251] projects work on improving intelligent transport services and providing an electronic language for data exchange.

When discussing data in the automotive sector, one central aspect **is access to in-vehicle data**, i.e. the data generated when using a car and the services related to its use. The Data Strategy mentioned a review of current legislation to open it up to more car data-based services[252]. Such ambition is also reiterated in the Sustainable and Smart Mobility Strategy, which stated that a new legislative act would propose a balanced framework guaranteeing fair and effective access to vehicle data by mobility service providers[253]. Opening up access to such data can expand the market entry of new players and reduce the costs associated with the testing of new data-enabled technologies. This initiative is strongly supported by consumer groups[254] and automotive suppliers[255].

As noted in a report by KPMG, OEMs, which have traditionally been reluctant to share collected data, have recently signed deals with both data aggregators and data marketplaces to make those data available[256]. OEMs are already involved in safe data sharing, which benefit society, as in the case of the

[248] See for more details: https://www.ccam.eu/.

[249] European Commission, 2020, *A European strategy for data*. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0066.

[250] For more details see: European Parliament, 2021, Legislative train schedule: A Europe fit for the digital age. Available at: https://www.europarl.europa.eu/legislative-train/theme-a-europe-fit-for-the-digital-age/file-data-act#:~:text=The%20initiative%20is%20about%20ensuring,on%20its%20Inception%20Impact%20assessment.

[251] For more details see: https://tn-its.eu/ AND https://www.datex2.eu/.

[252] European Commission, 2020, *A European strategy for data*. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0066.

[253] European Commission, 2020, *Sustainable and Smart Mobility Strategy*. Available at: https://ec.europa.eu/transport/sites/transport/files/legislation/com20200789.pdf.

[254] See for example: BEUC, 2021, *Urgent need for a legislative proposal on access to in-vehicle data and functions*. Available at: https://www.beuc.eu/publications/beuc-x-2021-062_beuc_and_fia_joint_letter_on_urgent_need_for_a_legislative_proposal_on_access_to_in-vehicle_data_and_functions.pdf.

[255] See for example: CLEPA, 2019, *Access to in-vehicle data and resources*. Available at: https://clepa.eu/wp-content/uploads/2019/10/CLEPA-Position-Paper-Access-to-Data-vF.pdf.

[256] See for a detailed discussion: KPMG, 2020, *Automotive Data Sharing*. Available at: https://assets.kpmg/content/dam/kpmg/no/pdf/2020/11/Automotive_Data_Sharing_Final%20Report_SVV_KPMG.pdf.

Safety-Related Traffic Information initiative[257]. This initiative brings together OEMs, Member States, and traffic authorities to exchange safety-related data[258].

Attention is to be put on the fact that data sharing needs to be critically assessed to ensure data privacy and safety, as uncontrolled access to in-vehicle data poses major threats to safety, security, and data protection[259].

Another key pillar of the EU's digital transformation is the development of a coherent and trustworthy environment for the development and deployment of AI technologies. The proposal for an **Artificial Intelligence Act** of April 2021[260] lays down different categories of risks for AI applications, ranging from minimal to unacceptable risks. This means that the obligations and requirements for AI applications will be proportionate to the impact of the application itself, limiting unnecessary burdens to developers and deployers of AI technologies. AI is a key component of CAM vehicles, and the proposed legislation is intended to increase and guarantee the trustworthiness of AI applications, facilitating the deployment and the acceptance of applications, such as advanced driver assistance systems, that are bound to increase road safety.

Given the increasing importance of semiconductors in the production of electric and autonomous vehicles, as discussed in section 3.1.4, on 19 July 2021, the Commission launched another industrial Alliance, the European **Alliance on Processor and Semiconductor Technologies**[261]. The overall objective of the Alliance is to identify current gaps in the production of microchips and the technology developments needed for companies and organisations to remain competitive. This is in line with the goals of digital sovereignty for Europe and aims to address the demand for the next generation of secure, energy-efficient, powerful chips and processors. The alliance will support a range of sectors and technologies, notably automotive and AI-enabled systems. It will do so by reinforcing the EU electronics design ecosystem and establishing the necessary manufacturing capacity. Currently, EU suppliers are strong in dedicated processors, i.e. micro-controllers, for embedded systems applications in automotive (37% global market share) and industrial uses, including machinery (17% global market share). These markets are expected to grow significantly in the coming years[262].

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257 See for details: https://www.dataforroadsafety.eu/.

258 Full statement: ACEA, 2021, *Auto industry actively sharing vehicle data, putting consumer choice, safety and security first*. Available at: https://www.acea.auto/message-dg/auto-industry-actively-sharing-vehicle-data-putting-consumer-choice-safety-and-security-first/.

259 As discussed in a recent debate held by the Kangaroo Group and ACEA, see: Kangaroo Group, 2021, *Virtual Debates 2021*. Available at: https://www.kangaroogroup.de/virtual-debates/ and ACEA, 2021, Interactive map- Automobile assembly ad production plants in Europe.
Available at: https://www.acea.auto/figure/interactive-map-automobile-assembly-and-production-plants-in-europe/.

260 European Commission, 2021, *Artificial Intelligence Act*.
Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1623335154975&uri=CELEX%3A52021PC0206.

261 Information available at: European Commission, 2021, Alliance on Processors and Semiconductor technologies.
Available at: https://digital-strategy.ec.europa.eu/en/policies/alliance-processors-and-semiconductor-technologies.

262 European Commission, 2021, *SWD on Strategic dependencies and capacities, SWD(2021) 352.*
Available at: https://ec.europa.eu/info/sites/default/files/strategic-dependencies-capacities.pdf.

5.3 Building resilience: cross-cutting issues for the automotive sector

As a result of the pandemic, there is wider recognition of the importance to analyse and assess strategic dependencies, both technological and industrial. Both the previously discussed dependencies on semiconductors and batteries highlight that Europe needs to better grasp where its strategic dependencies are and how they might develop in the future.

The Commission mapped **strategic dependencies** in a separate document[263], such as raw materials, batteries, and semiconductors. Beyond dependencies in European value chains, there are also risks associated with insufficient **access to skilled labour** to drive the twin transition.

5.3.1 Addressing strategic dependencies in automotive

Demand for raw materials is projected to double by 2050, making diversified sourcing essential to increase Europe's security of supply. CRMs are crucial for markets such as e-mobility, batteries, renewable energies, and digital applications. On 3 September 2020, the Commission adopted the **Critical Raw Materials action plan**[264], which outlines a set of actions to tackle vulnerabilities in the raw materials supply chains, which is a key component of the EU automotive sector, especially in light of the twin transition.

The first action under the action plan was the launch of the **European Raw Materials Alliance** in October 2020. Its mission is to close the gaps in existing supply chains, securing access to CRMs and other advanced materials and 'breaking' deficiencies such as the lack of technologies, capabilities and skills in the EU. In the first phase, the alliance will work on stepping up urgently needed resilience with regard to the rare earths and magnets value chains, on the one hand, and the raw materials for energy storage and conversion, on the other[265].

Downstream manufacturers such as automotive OEMs need to provide strong support to develop resilient European supply chains. Member States and industry can assess the situation and decide on the investments needed for the production of rare earths and their refining, magnetic alloys, magnets and their recycling, building on the investment pipeline prepared by the alliance. Regarding battery raw materials, the **EU foresight study on Critical Raw Materials**[266] estimates, for a high-demand scenario, an annual EU demand of 500,000 tonnes of nickel for e-mobility and renewable energy by 2030. The alliance has identified investment projects with the potential to increase production from 10,000 tonnes to 100,000 tonnes nickel capacity per year, representing 20% of the projected EU annual demand in 2030[267]. To partially address this demand, the **proposed new Batteries Regulation**, which is part of the Circular Economy Action Plans, proposes to introduce minimum recycled content in batteries[268].

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[263] Ibid.

[264] European Commission, 2020, *Critical raw materials resilience: charting a path towards greater security and sustainability*. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0474.

[265] See for more details: European Parliamentary Research Service, 2020, *Critical raw materials for the EU*, European Parliament. Available at: https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/659426/EPRS_BRI(2020)659426_EN.pdf.

[266] European Commission, 2020, *Critical Raw Materials for Strategic Technologies and Sectors in the EU – A foresight study*. Available at: https://ec.europa.eu/docsroom/documents/42881.

[267] European Commission, 2021, *SWD on Strategic dependencies and capacities, SWD(2021) 352*. Available at: https://ec.europa.eu/info/sites/default/files/strategic-dependencies-capacities.pdf.

5.3.2 Addressing skill shortages in automotive

Furthermore, as the twin transitions gather speed, Europe will need to ensure that **education and training** keep pace. Making lifelong learning a reality for all will become all the more important: the twin transition in the automotive sector, as previously discussed, will greatly affect employment across European factories (see sections 2.1.2 and 3.1.2). For industry workers, digitalisation, automation and advances in artificial intelligence will require an unparalleled shift in their skill set. In the global race for talent (see section 0), Europe needs to increase investment in skills, and life-long learning should become a reality.

On 1 July 2020, the Commission launched the **European Skills Agenda** for sustainable competitiveness, social fairness and resilience[269]. One of the main elements of the agenda is the **Pact for Skills**. Each Pact sets up large-scale partnerships in strategic industrial ecosystems heavily affected by the current crisis and the priority areas identified in the European Green Deal to achieve ambitious commitments. Among the first European skills, partnerships in key industrial ecosystems are the one for the automotive sector. The ambition to upskill 5% of the workforce each year would result in around 700,000 people being upskilled throughout the entire ecosystem, representing a potential overall private and public investment of EUR 7 billion starting with regional pilot schemes[270].

[268] Mandatory minimum levels of recycled content would be set for 2030 at 12 % cobalt; 85 % lead, 4 % lithium and 4 % nickel. As of 2035, increasing to 20 % cobalt, 10 % lithium and 12 % nickel. See: European Parliamentary Research Service (2021) New EU regulatory framework for batteries Setting sustainability requirements.

[269] European Commission, 2020, *Commission presents European Skills Agenda for sustainable competitiveness, social, fairness, and resilience*. Available at: https://ec.europa.eu/social/main.jsp?catId=89&furtherNews=yes&newsId=9723&langId=en.

[270] For more information see: European Commission, 2020, The Pact for Skills: mobilising all partners to invest in skills. Available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_20_2059. For more up to date information on further development of the alliance, see https://automotive-skills-alliance.eu.

6. CONCLUSIONS AND RECOMMENDED POLICY ACTIONS

In light of the identified strengths, weaknesses, opportunities and threats in sections 2.3 and 3.3, we find that the EU and relevant stakeholders identified many of the issues at stake and have put various policies in place to ensure the competitiveness of the EU automotive sector. For example, industrial alliances have proven effective in bringing together industry and increasing battery investments. Similar alliances for semiconductors and hydrogen are being put in place, and the action plans for the circular economy and raw materials aim to reduce dependencies. The importance of enabling infrastructure has also been recognised with the Alternative Fuels Infrastructure Directive and the 5G Action Plan. Finally, the Pact for skill and the Automotive Skills Alliance aim to address the skill shortage.

All in all, many policy decisions have been made at the European level to support the green and digital transition for a resilient automotive sector. However, there are also certain gaps and room for further action. For example, the differences in charging and digital infrastructure deployment across the EU Member States or the lack of strong digital and ICT players in the EU. We, therefore, have identified several policy recommendations that could further support the green and digital transition of the EU automotive sector:

- **Recommendation 1:** Ensure supply chain resilience for strategic and critical raw material;
- **Recommendation 2:** Simultaneously drive the local sourcing and 'greening' agenda;
- **Recommendation 3:** A green transition that works for the environment, industry and workers;
- **Recommendation 4:** Ensure that the expansion of the infrastructure for charging or fuelling EVs is adequate in terms of quality, functionalities, and coverage across Member States;
- **Recommendation 5:** Promote the development of skills in digital, software and electrical engineering and increase access to skills across the EU;
- **Recommendation 6:** Data sovereignty – respecting EU values in the collection, transfer, and sharing of data;
- **Recommendation 7:** Enabling European SMEs to better integrate with the automotive global value chain;
- **Recommendation 8:** Looking ahead to the next transition - supporting CAV technology.

Recommendation 1: Ensure supply chain resilience for strategic and critical raw material

The high import dependence on strategic and critical raw material (CRM), as alluded to within 2.1.2, if unresolved, will have a serious impact on the sustainability of the EU automotive industry. Indeed, the COVID-19 pandemic "stress-tested" the CRM global value chain to the point that semiconductor shortages and the over-dependence on China for Li-ion batteries severely disrupted European OEM production. Moreover, high demand for CRM coupled with slow reactions by mining companies could lead to future bottlenecks for CRM.

While the Li-ion battery supply situation has improved through the unprecedented increase in Li-ion new battery plants throughout the EU, large European manufacturers are still conspicuous by their absence, meaning that there is still scope, not only to fortify the Li-ion battery supply chain but for European MNCs to forge closer alliances with the top 10 EV battery producers.

Europe no longer competes with the Far East and Taiwan, in particular, in wafer fabrication. However, the key issue is not to compete head-to-head in the wafer fab, but, rather, through industrial alliances, enable the development of key technologies.

The case for OEMs and first-tier suppliers to develop their own semiconductor design competencies has never been stronger. From interviews, some OEM participants did not see semiconductor design as a core activity, but this is likely to change as more OEMs, and tier 0.5/1 suppliers become 'fabless' players.

Consequently, a **CRM (critical raw material) resilience plan** should:

- Follow-up on existing initiatives (e.g. the European Raw Materials Alliance) and complete the mapping, quantification, and environmental impact assessment associated with the extraction of Li-ion related inputs (cobalt, quartz, manganese etc.) across the EU Member States. In addition, agreements supporting sustainable mining and economic development could be investigated between EU and resource-rich countries;
- Not understate the non-EU-owned capacities for Li-ion battery manufacture currently being installed in Europe and motivate EU OEMs and suppliers to forge strategic alliances with the top 10 global EV battery producers - not to learn about battery production techniques but to establish R&D alliances to develop the next generation of Li-ion batteries thereby sustaining competitiveness; and
- Place a heavy emphasis on semiconductor design for EU companies - not just to keep pace but to ultimately establish a global lead in ASIC (application-specific integrated circuit) design and development, specifically in terms of EV transmission modules, regenerative systems, and the deployment of CAVs. As stated, for wafer fabrication and even assembly and test, European players will continue to find it challenging to compete with the Asia Pacific region. However, from a European perspective, innovation holds the key to sustaining improved competitiveness. Otherwise, innovation in the Far East and North America will over-shadow the EU and thus exacerbate over-dependencies on global sourcing.

Recommendation 2: Simultaneously drive the local sourcing and "greening" agenda

Environmentally, it is imperative to track emissions and the carbon footprint end to end right along with all elements of the automotive supply chain. This topic is resonating with a rapidly rising number of consumers to the point it is already a key differentiator for the record number of buyers with a commitment or intention to purchase an EV.

The eagerness to drive a new car out of a showroom with zero emissions makes for a compelling proposition. However, the cumulative metric tons of CO2 to get to the point whereby a new car arrives in the showroom makes this once compelling proposition significantly lose its appeal. There are many interdependencies at play, but in summary, **the greener the end-to-end automotive supply chain, the higher the demand for EVs, thereby representing the confluence of a strong environmental and commercial viability case.**

The environmental topic will only get 'hotter, and thus when considering the raft of initiatives being implemented by the EU and, in the pipeline, the European Parliament must be alerted to fully consider the environmental aspects for the whole value chain. Again a balanced view is needed. Although some environmental groups are, understandably, already rather vocal on sourcing CRMs like cobalt, (e.g. lawsuits over Congolese child cobalt mining deaths[271]), technological advancement could result in less raw material needed for EV battery production over time.

[271] The Guardian. (2019). Apple and Google named in US lawsuit over Congolese child cobalt mining deaths.

Additionally, Europe's dependency on imports of CRMs is expected to significantly decrease as over 20% of lithium and nickel, and 65% of cobalt needed for battery production could come from recycling within the next 10 to 15 years.

Burgeoning investment opportunities stimulate new business model development and a new generation of exceptionally innovative companies, like Sweden's Northvolt, which is accelerating the transition to a decarbonised future by supplying sustainable Li-ion cells and bringing the likes of BMW and VW Group with them as strategic partners. Volvo, owned by the Chinese company Geely, in 2021 entered a 50/50 joint venture with Northvolt featuring a new R&D centre and new EV battery gigafactory expected to employ 3,000 people.

Consequently, an '**End-to-end' automotive supply chain 'greening' plan** should:

- Rigorously apply emission and CO2 testing 'upstream' to alert European buyers to refrain from sourcing strategies that are still creating significant carbon footprints in other parts of the world, which still negatively impacts the investment climate for all;
- Develop guidelines for European companies sourcing semiconductors from wafer fabrication plants, including the world's largest wafer fab company - TSMC, Taiwan. Beneath the veneer of clean rooms and advanced technologies, which significantly contribute to the manufacture of environmentally friendly products, lies an industry based on litigation[272]that can adversely impact the environment. From semiconductor workers becoming unwell, the integrated circuit industry can cause groundwater and air pollution and generate toxic waste;
- Incorporate the two recommendations above within a monitoring and transparency evaluation framework tracking and quantifying the CO2-based value and supply chain of automotive-related electromobility; and
- Showcase the entrepreneurial spirit and innovation demonstrated by the likes of Sweden's Northvolt to motivate new European entrants to the EV battery development, production and recycling segments, thereby counterbalancing the dominance of China, South Korea, and Japan.

Recommendation 3: A green transition that works for the environment, industry and workers

In recent years, the EU automotive sector has increasingly started embracing EVs (and PHEVs), also thanks to the more stringent emission rules put in place by European Policymakers, as discussed in chapter 2. The legislative proposals introduced by the 'Fit for 55' package further increase ambitions. Specifically, automotive manufacturing will have to adjust to new CO2 emission standards for vehicles. The proposed amendment of the regulation setting CO2 emission standards for cars and vans calls for average emissions of new cars to come down by 55% from 2030 and 100% from 2035 compared to 2021 levels.

From a purely environmental perspective, these ambitions are needed. Economically, however, these ambitions entail a radical transition that challenges the transport sector. Specifically, for the automotive value chain, it requires a full transition towards BEVs or green HFCs and a stop of production for both PHEVs and ICE vehicles. Unsurprisingly, representatives from the automotive sector are concerned about these targets.

European policymakers should therefore take a comprehensive view when assessing the different proposals under the Fit for 55 package and discuss with stakeholders how these ambitions

[272] Good Electronics, 2019, South Korean Government admits 'relatedness of fatalities and illness to the South Korean semiconductor industry.

can be achieved. For one, both BEVs and HFCs will require an increased pace of infrastructure deployment across the EU (see recommendation 4) as well as a stark increase in climate-neutral energy supply.

In addition, our research showed that, in particular, smaller suppliers would face difficulties in implementing the green transition as they lack internal financial capabilities, access to financing and skills to adapt production to the changes in the automotive value chain.

Therefore, to support the greening of the sector and ensure that disruptions caused by the transition are minimised, **European policymakers should consider flanking mandatory targets with supporting measures**:

- An existing tool is the **Just Transition Mechanism** of the EU. Specifically, the Just Transition Fund, which targets regions in transition and the InvestEU "Just Transition" scheme, and provides advisory support and budgetary guarantees to mobilise private investment, are instruments that could support the sector. Member States are tasked to submit their Territorial Just Transition Plans. Policymakers should pay attention that regions depending on automotive suppliers are taken under consideration in these plans. In addition, funding from the National Recovery Plans could be allocated towards the green transition of the automotive sector;
- Beyond this, by working together with multiplier organisations such as business associations, industry clusters but also OEMs, EU policymakers should **raise awareness** across the automotive value chain about the upcoming transition in order to give companies sufficient warning to adapt skills, technologies, and production. Specifically, OEMs, but also larger automotive suppliers that are generally better prepared for the upcoming changes, should be encouraged to include their supply chain partners in their discussions when transforming production lines and how this will affect future demand for parts, services and technologies across the value chain.

Recommendation 4: Ensure that the expansion of the infrastructure for charging or fuelling EVs is adequate in terms of quality, functionalities, and coverage across Member States

As alluded to in Chapter 2, one of the main barriers to the widespread adoption of EVs is the lack of sufficient charging infrastructure. The lagging and uneven distribution of charging points give consumers a good reason to maintain the "range anxiety" that has characterized the attitude of many buyers regarding EVs. The adoption of electric cars, nonetheless, has been accelerating while the current rate of expansion of the charging infrastructure is insufficient to achieve the ambitious goals of the 'Fit for 55' package. As outlined in Chapter 5, this bottleneck is well mapped, and the Alternative Fuels Infrastructure Directive under the Sustainable and Smart Mobility Strategy **aims to accelerate the expansion of the charging and refuelling network for electric and hydrogen-fuelled vehicles across the EU**.

Besides the need to accelerate infrastructure deployment, the Commission rightly identifies in the new Proposal several important shortcomings of the previous Directive, such as the **lack of ambition, consistency and coherence in national strategies that led to an insufficient and unevenly distributed infrastructure**, persistent interoperability issues with physical connections, new issues over communication standards – including data exchange among the different actors in the electro-mobility ecosystem – the lack of transparent consumer information and common payment systems limiting acceptance.

The revision proposed in July 2021 goes a long way in addressing some of the main shortcomings of the current infrastructure deployment process. Member States would be required to offer recharging stations for BEV and PHEV registered in their territory, install charging (including fast-charging) and fuelling points at regular intervals on the major highways, provide open and standardised access to public charging points, payment methods, and wide public and dynamic access to data about the charging infrastructure.

Nonetheless, there are several areas wherein forward-looking policies can be tailored to guarantee an accelerated and appropriate adaptation of the current network in the medium to long term:

- The **quality of the charging network** is an important parameter to guarantee the full use of both BEVs and PHEVs. Nonetheless, the current proposal remains silent about fast charging points in urban areas. Following the expansion of the EV customer base, the European Parliament should consider measures to further address the quality of the urban charging network, for example, the need for fast charging stations in public parking spaces, highways, and retail destinations;
- The current mechanisms are unlikely to completely solve **inequalities in the availability of infrastructure among Member States**, among other reasons, because they are partially connected to the local registrations of EVs. Given the structural and persistent inequalities among Member States, we advise the European Parliament to deepen direct financial incentive mechanisms that allocate funds for infrastructure deployment. This should be done explicitly considering infrastructure gaps in Member States regarding the necessary quality and quantity of charging points vis-à-vis each state's financial needs and availability;
- **Smart charging (V1G) and vehicle-to-grid (V2G)** functionalities add value not only to the energy infrastructure and their operators but also have the potential to enable new business models that accelerate the uptake of EVs and the accompanying infrastructure. Some possibilities include local grid operators offering pay-per-use models that involve installing and managing the associated infrastructure. Moreover, the standards and technical specifications currently being promoted should be made compatible with V2G functionalities (e.g. bi-directional chargers and DC charging). In that context, the European Parliament should promote the deepening of discussions between grid operators, regulators, and the automotive sector, to establish common technical standards that prepare both grid and vehicles for V1G and V2G functionalities and the accompanying business models in a coordinated manner.

Recommendation 5: Promote the development of skills in digital and software as well as electrical engineering and increase access to skills across the EU

The transformations reshaping the automotive sector in the EU might lead to a strong repositioning of the sector in the coming years. Such transformations bring about – among others – important questions related to human capital. On the one hand, as noted in Sections 2.1.2 and 2.3, although research is still ongoing on the matter, the transformation of the automotive sector away from the ICE might have massive employment repercussions, requiring the reskilling of workers in assembly plants, part manufacturers, and in the field of vehicle maintenance. On the other hand, as noted in sections 2.1.2, 3.1.2 and 4.4, qualified figures and talents in specific subsectors are not readily available to meet the EU's businesses' demand, leading to global competition to attract and retain such figures. Businesses are already reporting a lack of staff with adequate digital skills. This 'red flags' the challenge for the EU to provide and attract sufficient talent within the new technology areas.

Recommendation 5.1: Ensure sufficient investment in digital and technical re/upskilling

The EU and the automotive sector are already addressing this issue with projects such as DRIVES, the Automotive Skill Alliance and the recently launched Pact for Skills for automotive (as noted in section 5.3.2). It is crucial to follow up on these initiatives, monitor their progress, and investigate how national measures can also contribute to the re/upskilling of the workforce in light of the twin transition. Given the different degrees of importance of the automotive sector across EU regions, it is **key for Member States to support industries and increase cooperation with them to facilitate the possible transition of workers away from traditional ICE related manufacturing**.

This can be done by expanding vocational training and in-work training schemes to upskill and accompany existing workers of the sector toward the professions that will be in growing demand in the upcoming years.

On that front, EU instruments such as the Just Transition Fund should be closely monitored to expand their scope if needed promptly (see also recommendation 3). Furthermore, where EU legislation is to steer technological change, attention needs to be given to the workforce. This is key in electromobility, where the phasing off of ICEs might have massive repercussions on the number of employed people in the sector. Therefore, it is central to monitor and maintain an open dialogue with all parts across the EU automotive value chain to actively support the twin transition while **ensuring that such transition does not disproportionally affect certain workers and EU regions**.

Recommendation 5.2: Encourage training in key fields and promote the retention of talents to maintain EU leadership and competitiveness

Big data analytics, software development, electrical engineering, battery chemistry, and related areas to develop electromobility and automated driving are key areas of concern. This shortage is a common trend across the globe, leading to increased competition to acquire such talents. Other than the aforementioned EU strategies specifically designed for the automotive sector, The Coordinated Plan on AI details two different strategies to achieve those goals:

- It proposes exchanges of best practices between the Member States on the use of the "blue card", the EU visa for talents, in order to reduce the burden on companies and high skilled third countries nationals interested in moving into the EU;
- It focuses on the importance of providing better synergies between EU companies and educational institutions, e.g. offering STEM-oriented PhDs in cooperation with leading and innovative industries.

Member States should prioritise and support the finalisation of such agreements and cooperation to attract young talents and women into STEM sectors. Incentives could include scholarships for prospective students with the agreement to spend a certain minimum number of years being employed in one of the partner EU industries. Such a scheme could help retain talent and assure a return for the public investment in higher education.

The European Parliament needs to monitor that Member States and European Commission follow-up on the commitments laid down in the Coordinated Plan for AI. Similar schemes could be expanded to other key technologies. It is important to note that policies to train and retain highly skilled figures benefit the automotive sector and favour synergies with other key compartments of EU leadership, such as aerospace. The convergence of the automotive industry with aerospace in areas such as carbon fibre composites, weight saving, rigorous quality requirements, sophisticated electronics, embedded systems, high precision-machined parts, and low emission propulsion will also continue to increase the demand for intellectual capital, particularly STEMs related.

Finally, Member States should be encouraged to **diligently review and upgrade skills and training incentives** to prioritise the provision of STEM-related competencies and capacities. The skills and training incentives should motivate domestic and cross-border companies of all sizes to further boost the number of STEM trained personnel. The European Parliament should advise Member States to move away from cost or profit-based incentives to behavioural and performance-based incentives. This sharpens the focus on desired impact in terms of digital skills matched with demand while facilitating monitoring and evaluation to that end.

While the extent of the incentives need not differentiate between SMEs and MNCs, the eligibility criteria for SMEs should be less onerous, thereby enabling them to compete for talent.

Recommendation 6: Data sovereignty – respecting EU values in the collection, transfer, and sharing of data

The digital transformation, which is reshaping critical industries across the EU, is strongly transforming the automotive sector, as thoroughly discussed in chapters 3 and 4. A safe, secure, and reliable infrastructure capable of high-speed data transfer to deploy CAVs is key. Furthermore, software-based digital services in the automotive sector will become more prominent in the coming years, increasing the importance of collecting and sharing data. This translates to concerns from EU citizens, enterprises, and countries about a loss of control over their data.

The EU has defended Europe's technological sovereignty via initiatives such as the 5G Action Plan and the Alliance on Processor and Semiconductor Technologies. Nevertheless, to develop competitive ecosystems for connectivity, the EU needs to create the conditions for companies to rival big players in the USA and China. Failing to do so, dependency on foreign players will increase in one of the most delicate fields, data.

As presented in chapter 5, the European Data Strategy paves the way for European data spaces. The European Common Mobility Data Space aims at facilitating the secure exchange of data across the continent. In the same vein, TN-ITS and DATEX II projects work on providing an electronic language for data exchange. The development of European data spaces for the use and sharing of automotive data is fundamental to maintaining competitiveness in the coming years. Same as under the Artificial Intelligence Act, the development of trustworthy technologies that fully respect privacy laws and safety standards can be the value proposition of EU technologies globally:

- Therefore, it is vital for the European Parliament to monitor existing and future initiatives and ensure the swift development of **secure European data spaces** fully compatible with privacy laws;
- Different car manufacturers, tech companies, and other players across the value chain are currently developing their own ecosystems, applications, and databases. While a European partnership on CCAM exists, there is a **risk of fragmentation** that might hinder the EU competitiveness vis-à-vis the USA and China. Therefore, the European Parliament must monitor upcoming legislative proposals to ensure coherent development of EU wide standards for data-enabled services in the automotive sector;
- In the upcoming legislative proposal for **access to in-vehicle data**, the European Parliament has a key role in balancing the cost-saving benefits of facilitating access to data and guaranteeing safety and security of accessing that information without creating risks to CAVs;
- Finally, given the increasing number of strategies and plans that have implications for **data sovereignty** in the EU, together with existing voluntary cooperation between industries and governmental bodies, such as the Safety-Related Traffic Information initiative or the Gaia-X initiative, the European Parliament is well-positioned to harvest best practices and inputs in order to steer the legislation that the European Commission will propose in the upcoming months, most notably on the Data Act and the proposal on access to in-vehicle data.

Recommendation 7: Enabling European SMEs to better integrate with the automotive global value chain

The importance of SMEs for sustainable and inclusive economic development is well-documented, and as mentioned in 1.2.1, across the EU, around 17,000 were active in the manufacture of vehicles and components. Whilst Germany accounted for the lion's share, the economies of countries like Poland, the Czech Republic, Hungary, Romania, and Slovakia are now inextricably linked to the fate of the automotive industry. For example, Slovakia now produces more cars per capita than any other country.

That automotive is the most integrated ecosystem in intra-EU value chains underscores the importance of a sector whereby over 45% of its production depends upon cross-border value chains within the EU. The challenge that many SMEs face is that they are overly dependent on parts that no longer feature within EVs, such as exhaust systems, carburettors and traditional electrical components like alternators and starter motors. Furthermore, with an EV costing at least 30% less than an ICE vehicle to maintain, the SMEs in Europe within the car repair/servicing and aftermarket components segments will inevitably face, at best, mounting cashflow pressure and at worst, significant redundancies, and bankruptcies.

Further intervention programmes are thus needed to enable SMEs to diversify and accelerate digitalisation to initially safeguard their position in existing supply chains and thereafter to advance to higher added-value products and services, thereby enhancing prospects for GVC integration. This, in turn, will place more pressure on SMEs to recruit intellectual talent in terms of Industry 4.0 and AI competencies in order to remain competitive, but this is easier said than done (see recommendation 5).

Amidst the COVID pandemic, as explained in 4.3, the overarching aim of most OEMs and top tier suppliers is to increase the resilience of their regional and global supply chains, to which end **digitalisation** is an essential tool. The implication for SMEs is that they have little choice other than going down the digitalisation route in order to grow and prosper by more effectively integrating with GVCs.

There is a raft of extensive and commendable EU initiatives aimed at fully unlocking SME potential across the Member States. Furthermore, as summarised within 5.1, the combination of EV and 'greening' related intervention is impacting SME development and creating new business opportunities. Access to finance, as echoed by interviewees, is still a constraint for many SMEs. While there are no shortages of initiatives and programmes on that particular topic, the rather **conservative banking and venture capitalist segments in Europe** can place the EU's SMEs and start-ups at a disadvantage vis-à-vis their North American and the Asia Pacific counterparts.

Notwithstanding the importance of access to finance, the recommendations move more in the direction of leveraging the EC's industrial and other related alliances along with the Strategy for Sustainable and Smart Mobility. Consequently, an **SME Automotive Global Value Chain Integration plan** should:

- Assist Member States in the **development of the 'next generation of supplier linkages programmes** specifically aimed at enabling automotive SMEs to leverage EU value chains as the 'departure point' for GVC integration. Although the success rate of linkages programmes is mixed, the Czech model, summarised in 4.3, worked exceptionally well. Three factors, in particular contributed to the success of the programme, which initially was EU funded: a) the programme was demand driven by automotive MNCs; b) selection of SMEs was based more on their potential than need and c) 100 percent public-private commitment. Lessons from this programme can be updated and upgraded by developing supplier development/linkages programmes at the heart of which digitalisation and 'greening' should be prioritised, thereby enhancing the prospects for SMEs to integrate with the automotive GVCs; and

- Exploit opportunities to expand the reach and impact of existing **automotive productive and innovative clusters**. From the interviews, feedback suggested a need for SME / OEM / top tier supplier dialogue platforms to be more accessible and thematic. While there is no need to 'reinvent the wheel' given the provision of world-class automotive cluster organisations, including EACN (The European Automotive Cluster Network) and the likes of ACstyria mobility cluster, with over 300 companies across automotive, aerospace and rail systems, there is a need to enable EU SMEs to interface with larger companies more easily, beyond their own region. SMEs, particularly from Central and Eastern Europe, find it challenging to establish contact with key players. Sharpening digitalisation, greening, and electromobility themed 'matchmaking' through the existing cluster network can facilitate greater regional sourcing while enabling SMEs to better integrate with GVCs via the European operations of OEMs and top tier suppliers.

Recommendation 8: Looking ahead to the next transition - supporting CAV technology

Vehicle technologies, compared to other consumer goods, take relatively long to penetrate markets due to high costs, durability and regulation. This is also true for CAV technologies. Current barriers can be divided into technical, legal and public acceptance barriers. In the context of Europe, two barriers are most important, the availability of infrastructure to test and roll out the vehicles and user acceptance. Plans to overcome these barriers should:

- Ensure **close collaboration between regulators and the automotive industry** to close the knowledge gap in regulation on testing. CAV technology is rapidly evolving, and it is a challenge for laws and regulations to reflect recent developments. Hence, both policymakers and companies within the automotive industry would benefit from closer collaboration and sharing of information. The CCAM partnership can serve as such a platform, however, it was also flagged in one of our interviews that it currently is a very open and voluntary format. A more top-down approach that provides targets and a mission-oriented approach could strengthen the platform's work;
- **Regulatory support for large scale testing**, contrary to the US, an environment for large scale testing is missing in Europe. Deploying CAVs in live situations on a large scale is not possible in Europe at the moment[273], which causes both delays in testing and launching automated vehicles. Only a few Member States have introduced national policies. In the declaration of Amsterdam Member States called on the Commission to develop a shared European strategy.[274] Coordination of R&I and testing activities across the EU will be required to address the current fragmentation. One way of achieving regulatory support for large scale testing is through a European network of living labs;
- A **European network of living labs** would create an environment where: new mobility solutions can be introduced and tested via a proper process of public and stakeholder engagement. A platform should be created where these living labs can exchange performance data for sharing the lessons learned and support the rapid uptake of successful solutions. In addition, a European network of living labs could create an environment where new options and governance models

[273] However, due to recent regulatory changes, large scale deployment will be possible on German roads by 2022.

[274] European Commission, 2018, *On the road to automated mobility: An EU strategy for mobility of the future*. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1527002536861&uri=CELEX:52018DC0283.

can be applied and tested with the direct and proactive engagement of citizens. In living labs, people can be engaged in the process of testing from the early stages of development. In this perspective, this would also contribute to greater acceptance of CAV technology by the public. The involvement of citizens in the early stages of testing would be an important step towards the belief that solutions adopted can really deliver what they promise[275]; and

- Public acceptance of CAV technologies depends on trust, price, willingness to pay, driving pleasure, safety. The policy would benefit from **public access to in-vehicle data**. This does not only have a cost-saving element but would be important in gaining the trust of future users. This initiative is strongly supported by consumers and the automotive industry. Currently, OEMs already use in-vehicle safety data sharing in the Safety-Related Traffic Information initiative.[276]

[275] Alonso Raposo, M., et al, 2019, *The future of road transport - Implications of automated, connected, low-carbon and shared mobility*, Joint Research Centre. Available at: https://publications.jrc.ec.europa.eu/repository/handle/JRC116644.

[276] CLEPA, 2019, *Access to in-vehicle data and resources*. Available at: https://clepa.eu/wp-content/uploads/2019/10/CLEPA-Position-Paper-Access-to-Data-vF.pdf.

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ANNEX A – ADDITIONAL MATERIALS

In the competence area of **software architecture** six companies out of the 21 relevant actors are European and three more are partially European or have relevant links. For **connectivity**, there are four European companies among the 17 relevant actors. Finally, for **autonomous driving** there are 8 European companies among the 33 relevant actors.

Table A.1 Competencies and actors in software, connectivity and automated vehicles

Competence area	Components	Relevant actors	
Software architecture	Operating system	Linux (Basis)	Daimler: MB.OS*
		Alphabet: Android Automotive OS	BMW: Operating System 7
		Tesla	Alibaba: AliOS
		VW Group: vw.os*	Tencent: AI in Car
	Connectivity; Cloud integration; Over-the-air updates	Qualcomm	Huawei
		QNX	Alibaba: Cloud
		Aurora Labs**	Amazon: Cloud
		Microsoft: Automotive Cloud (in cooperation with VW Group)	
	Mainframe; Bus systems (ethernet)	Continental: e.g. VW ID.3	Nvidia
		Bosch, ZF	Magna
		Faurecia	Tesla
Connectivity	User interface	Amazon: Alexa	Daimler: MBUX
		Alphabet: Google Assistant	Microsoft Azur Cognitive Services
		Apple: Siri	
	V2X/IoT	Amazon (AWS)	Microsoft (Azure)
		BMW	Tesla
		Daimler	VW Group
	Digital service platform	Alibaba	Apple (AppStore)
		Alphabet (Google PlayStore)	Baidu
		Amazon	Tencent (QQ, WeChat)
Autonomous driving		**… for subsystems**	**… for complete systems**
	Sensors (e.g. camera, lidar, radar)	Bosch	• Alphabet: Waymo • Amazon: Zoox • Apple
		Continental	
		Intel: Mobileye	

Competence area	Components	Relevant actors	
		TI	• Aptiv/Hyundai: Motional • Aurora (Uber-Investment) • AutoX • Baidu: Apollo • Didi Chuxing • GM: Cruise • Intel: Mobileye / Moovit • Pony.AI (i.e. Toyota investment • Tesla • VW Group: ArgoAI (together with Ford)
	Other hardware	Aptiv (e.g. Audi)	
		Bosch	
		Continental	
		Nvidia: Xavier	
		Samsung: Harman	
		ZF	
	Software (e.g. image processing, AI)	Electrobit	
		Green Hills	
		Intel: Mobileye	
		Microsoft Azure	
		Nvidia	
		QNX	
	Data	Alphabet: Google Maps	
		Here Technologies	
		Inrix	
		Tesla	

Source: CAM Innovation Database, 2021. Note: *Currently in development; **Israel based, but German subsidiary company. Dark blue are EU based actors, light blue with EU based actors involvement.

This study provides an independent overview on the automotive industrial landscape in the EU. Specifically, the study assesses green and digital trends currently reshaping the automotive sector and provides recommendations considering the adequacy and consistency of ongoing and future EU actions.

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