Monitoring the twin transition of industrial ecosystems

MOBILITY, TRANSPORT AND AUTOMOTIVE

Analytical report

Authors: Djerdj Horvat, Daniel Berner, Henning Kroll, Johannes Jasny, Fraunhofer ISI

Data analysis supported by: Kincsö Izsak, Carmen Moreno, Yari Borbon, Paresa Markianidou, Owen McColgan Technopolis Group

TABLE OF CONTENTS

TABLE OF FIGURES

Executive summary

Measuring performance and monitoring change within an industrial ecosystem are vital components that enable policymakers and industry stakeholders to track progress over time and obtain valuable feedback on whether the system is moving in the desired direction. This report is a contribution to the 'European Monitor of Industrial Ecosystems' (EMI) project, initiated by the European Commission's Directorate General for Internal Market, Industry, Entrepreneurship, and SMEs, in partnership with the European Innovation Council and SMEs Executive Agency (EISMEA). Its primary objective is to present the current state and the advancements achieved over time in terms of the green and digital transition of the European **Mobility, Transport, and Automotive Industrial Ecosystem**. From here on, referred to as the mobility ecosystem.

The mobility ecosystem is characterised by long and complex supply chains, dominated by a few global players and a large number of small and medium-sized enterprises. The ecosystem plays a significant role in the EU's economy, accounting for 7.5% of total EU value added and employing around 14.6 million people directly and 16 million indirectly. It is primarily characterised by small and medium-sized companies, which make up an impressive 99.7% of all enterprises, totalling approximately 1.8 million firms.

Over the past few years, Europe has undergone a noteworthy twin transformation: one digital and the other environmentally conscious, in pursuit of a more sustainable, low-carbon, and adaptable mobility infrastructure. This two-pronged shift encompasses both the supply side of technology, revolving around research and development, as well as the emergence of new market entrants. Moreover, the demand side, concentrated on the effective implementation of these technologies, also assumes a pivotal role for the transition. These combined forces are crucial in preserving Europe's competitiveness on the global stage, a matter of increasing significance given the ascendance of China, the USA, and South Korea as formidable players. In the subsequent sections, we summarise the key findings of this study, underscoring the paramount and current drivers propelling the digital and green transition within the European mobility ecosystem.

Key findings about the green transition

The mobility ecosystem consumes a significant volume of natural resources, including fuel, water, materials, land and energy. The assessment of the environmental impact of the mobility ecosystem of the EU27 conducted in the framework of this study indicates a **negative trend and increasing pressures over the recent years in several dimensions such as the extraction of raw materials, the emission of greenhouse gas emissions, particulate matter, and damage to biodiversity**. In terms of greenhouse gas emissions of CO2 (measured in tonnes), the mobility ecosystem is above the global average, and it is the second industry after agri-food emitting the most C02. Particulate emissions from the ecosystem reached a peak in 2021 and is likely to continue to grow. Although material extraction declined between 2011 and 2015, it has risen sharply since 2016, reaching an all-time high in 2020. Material extraction is well above the global average. Despite these negative trends, there are significant efforts towards environmental sustainability.

European companies in the mobility ecosystem continue to solidify their prominent position in the realm of cutting-edge green technologies, asserting their dominance in patent specialisation alongside the world's foremost nations. This assertion is particularly evident in key areas such as batteries, advanced sustainable materials, efficient energy generation and combustion, as well as hydrogen innovation. Our comprehensive startup dataset underscores this trend, displaying that companies engaged in developing technological solutions for electric vehicles constitute the largest group of new players within this ecosystem, and their numbers are expanding at a remarkable pace.

Particularly notable is the **rapid increase in electric vehicle-focused startups**. This indicates a substantial scope for innovation and technological advancement, highlighting that the sector is still in its emerging phase. In contrast, our analysis has unveiled a notably inconsistent trend in the emergence of new companies within the Mobility as a Service (MaaS) area since 2016. This dynamic can be attributed to demand-side factors and the complexities inherent to the MaaS system. Nonetheless, Europe still commands a leading position in terms of the number of unicorns within the MaaS domain, diverging from the battery and electric vehicle sectors where China and the USA take the lead.

To supplement our data, we conducted a survey-based inquiry covering 355 companies operating within the mobility ecosystem. Our results reveal that **nearly half of the companies in the sector have amplified their investments in green transformation**, underscoring a collective commitment to environmental sustainability. Notably sought-after fields for these green technology adopters include energy-saving and recycling-related technologies, closely followed by renewable energy and clean production innovations. However, **despite the engagement in green technology investments, the survey found relatively lower adoption rates for any single type of green technology**, making the current state of the uptake and diffusion of the green transition among the SMEs of the mobility sector appear sluggish.

In the study, we show also that **the European mobility ecosystem has experienced a surge in venture capital investment, particularly in firms at later technological development stages.** Investments in such companies have more than tripled since 2020, totalling over EUR 6 billion. However, foreign direct investments in the ecosystem peaked in 2018 and declined until 2021. In terms of public procurement activities relevant for the ecosystem, green transition technologies have seen the highest relative growth in the number of notices, particularly hybrid and emission-free technologies. Meanwhile, hydrogen and electric vehicles have experienced the highest absolute growth in the number of notices.

Our study also recognised the shortage of skilled engineers as one of the main challenges faced by companies in the European mobility ecosystem. As the whole ecosystem transforms to be more sustainable and technology-driven, competences and skills of employees are becoming increasingly crucial. Nevertheless, **our study finds, surprisingly, that only 4% of professionals in the mobility ecosystem state having green transition related skills** on their LinkedIn profiles. The **supply and demand gap for green professionals appeared to be especially pronounced in fields like circular economy, low carbon technologies, energy-saving technologies, and renewable energy**, all of which are highly relevant, for example, for the upcoming battery sector.

Key findings about the digital transition

Despite the ongoing and consistent growth observed in patent applications across various domains, our comprehensive analysis reveals a concerning decline in the global share of patent applications originating from European companies within the digital technology field and in the mobility ecosystem. This trend shows a potential future risk for Europe's technological competence and thus sovereignty, particularly in the realm of mobility solutions.

Our findings underscore Europe's relative lag in some pivotal digital domains. Notably, areas such as mobility-centric artificial intelligence, the Internet of Things, and autonomous vehicles exhibit noticeable gaps in European innovation. However, amidst these challenges, our analysis illuminates a noteworthy surge in tech startups within the mobility technology landscape. These emerging companies are distinctively anchored in cutting-edge technologies like artificial intelligence, the Internet of Things (alongside its associated connectivity facets), big data, and blockchain. Interestingly, classical sectors of digital technology—such as conventional software-based services, robotics and automation—are dwindling in significance, signifying a shift in the technological landscape. In contrast, our survey data shows a significant interest within the European mobility ecosystem for advanced digital enabling technologies. These primarily encompass a relatively strong demand for online platforms, cloud technologies, and the underlying bedrock of big data. Equally noteworthy are the manifold technology use cases across the entire mobility value chain in fields such as artificial intelligence, the Internet of Things, augmented and virtual reality, or robotics. However, mirroring the ambiguous trends in the demand for environmentally conscious solutions, did the survey find only relatively low adoption rates for any single type of digital technology within the surveyed SMEs, despite these SMEs having stated to have increased their investments in the digital transformation in recent years.

This confluence of insights underlines a pivotal implication: despite the acknowledged challenges within the ecosystem, a promising business field emerges for **prospective digital mobility tech startups and other technology enablers.** The key lies in their adeptness at embracing novel, data-centric servitisation models. As the EU seeks to carve its niche in the digital future, these trends underscore a tangible potential for innovative enterprises to thrive and spearhead the evolution of the mobility solutions landscape. The mobility ecosystem is challenged by a range of mobility tech startups that foster digital transformation in particular in the fields of **software-based mobility services, Internet of Things and connected mobility, big data and Artificial Intelligence.**

However, as these new entrants emerge as key players leading the digital transformation of the mobility ecosystem, traditional SMEs, the vast majority of companies active in the ecosystem to-date, are increasingly facing the threat of missing out on these opportunities. Especially the **relatively low adoption rates of advanced digital technologies among the SMEs of the mobility ecosystem, despite their increased investments of recent years**, hints at reasons other than, a lack of relevance, strategic focus, or investment capacities for the limited technology uptake.

With regard to the demand and supply for digitally skilled professionals in the mobility industrial ecosystem, **digital professionals are in high demand for Internet of Things solutions, cloud computing, artificial intelligence, robotics, cybersecurity, and in the big data** domain.

Collaborative actions, such as for instance public-private initiatives, can play a significant role for increasing the diffusion of green and digital technologies. These multi-stakeholder partnerships have already shown to benefit both the development and uptake of green and digital technologies. As exemplified by the cases of the data ecosystem initiatives Gaia-X, respectively Catena-X, as well as several public-privately operated technology centres that have emerged and successfully contributed to the twin transition all across the European Union Member States. Catena-X has the potential to empower the automotive industry, a significant catalyst in the mobility ecosystem, to build up the digital capabilities for a successful twin transition. This collaboration is aimed at enabling the automotive industry to effectively embrace a data-driven value chain, leading to innovation and progress within the sector, including both digital and green technology use cases and business opportunities.

1. Introduction

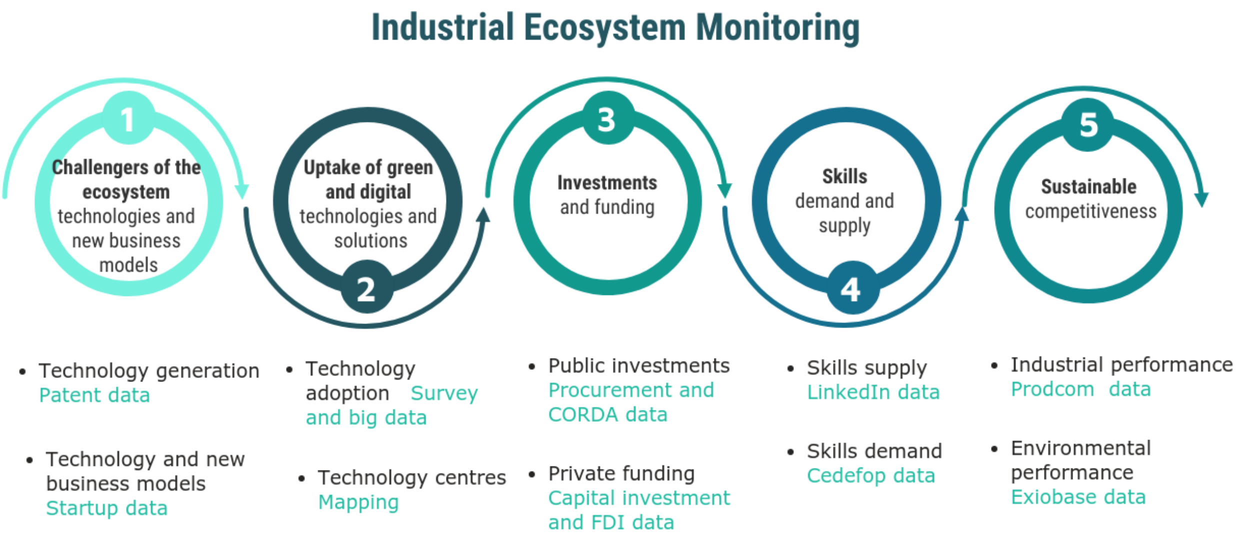
1.1 Objectives

This report has been prepared within the '**European Monitor of Industrial Ecosystems**' (EMI) project, initiated by the European Commission, Directorate General for Internal Market, Industry, Entrepreneurship and SMEs and the European Innovation Council and SMEs Executive Agency (EISMEA). The overall objective of the project is to **contribute to the analysis of the green and digital transformation of industrial ecosystems** and progress made over time.

The EU's updated industrial strategy[1] has identified 14 industrial ecosystems[2] – one of them being '**Mobility, transport and automotive**' - that is in the focus of this report. The industrial strategy defined industrial ecosystems as encompassing all players operating in a value chain: from the smallest startups to the largest companies, from academia to research, service providers to suppliers. The notion of ecosystems captures the complex set of interlinkages and interdependencies among sectors and firms across the EU. Industrial transition is driven by technological, economic, and social changes, and in particular by green and digital technologies and the shift to the circular economy. The process is however characterised by complex, multi-level, and dynamic development. To make transition sustainable, technological change needs to be coupled with new business models, the necessary investments, skills, regulatory framework conditions and behavioural change across the ecosystem.

Measuring performance and change is vital to allow policymakers and industry stakeholders to track progress over time and get feedback whether the system is moving in the desired direction. To measure performance, a dedicated **monitoring and indicator framework** has been set up for the purposes of this project with an aim to capture them in regular intervals (see the overview of the monitoring framework in Figure 1).

Figure 1: Overview of monitoring industrial ecosystems and relevant data sources



Source: Technopolis Group, IDEA Consult and Fraunhofer ISI

---

[1] European Commission (2020). A New Industrial Strategy for Europe, COM/2020/102 final and European Commission (2021). Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe's recovery, COM(2021) 350 final

[2] The 14 industrial ecosystems include: construction, digital industries, health, agri-food, renewables, energy intensive industries, transport and automotive, electronics, textile, aerospace and defense, cultural and creative culture industries, tourism, proximity and social economy, and retail

The indicator framework includes a **set of traditional and novel data sources that allow shedding new light on ongoing transformation patterns.** The novelty of the analysis lies in the exploratory and innovative data sources used across the different chapters. Due to its effort to analyse industrial ecosystems using a more or less standardised set of indicators, the study cannot address all aspects of the green and digital transition. Therefore, additional analysis and industry-specific data sources should be used to supplement a full assessment.

The **methodological report** that sets the conceptual basis and explains the technical details of each indicator is found in a separate document uploaded on the EMI website. Moreover, some of the specific industry codes used throughout this analysis have been also included in Appendix B. The green and digital technologies that have been taken into account in this study are presented in Figure 2.

Figure 2: Main technologies monitored in the project

Green transformation
Advanced Sustainable Materials
Biotechnology
Energy Saving technologies
Clean Production technologies
Renewable Energy technologies
Solar Power
Wind Power
Other (geothermal, hydropower, biomass)
Recycling technologies
Circular business models

Digital transformation
Advanced Manufacturing & Robotics
Advanced Manufacturing
Robotics
Artificial Intelligence
Augmented and Virtual Reality
Big Data
Cloud technologies
Blockchain
Digital Security & Networks/ Cybersecurity
Internet of Things
Micro- and Nanoelectronics & Photonics
Online platforms

Source: Technopolis Group, IDEA Consult and Fraunhofer ISI

This report contributes to the analysis of the **key pillars put forward in the 'Blueprint for the development of transition pathways'**[3] of the Industrial Forum developed in 2022.

1.2 Definition of the ecosystem

As defined in the European Commission Annual Single Market Report, the mobility, transport and automotive industrial ecosystem includes the following three segments: **automotive, rail and waterborne**[4]**,** to which in line with a recently adopted resolution of the European Parliament[5] **cycling** may be added as a further area to which future attention needs to be directed. From here on, we refer to it as the '**mobility ecosystem**'.

The ecosystem is characterised by long and complex value chain chains[6]. It is dominated by a few enterprises that became global players on the one hand, and a huge number of suppliers in many vendor areas on the other. Considering the number of companies, the ecosystem is dominated by small and medium sized companies the number of which amounts to around 1.8 million firms representing over 99.7% of all enterprises. According to Eurostat National Accounts, the gross value added of the ecosystem in 2019 was around

[3] https://ec.europa.eu/docsroom/documents/49407/attachments/1/translations/en/renditions/native
[4] European Commission, 2021 Annual Single Market Report Brussels, 5.5.2021 SWD (2021) 351 final
[5] https://www.europarl.europa.eu/doceo/document/B-9-2023-0102_EN.html
[6] https://ec.europa.eu/docsroom/documents/48535

EUR 906 billion, accounting for 7.5% of the total EU value added. The ecosystem employed 14.6 million people in 2018 directly, and at least 16 million including indirect jobs enabled by tight collaboration with other industrial ecosystems, like information and communication technologies and electronics.

1.3 Industry state of play

The growing concern over climate change and the need to reduce emissions has made it necessary for many countries to shift to more sustainable and low-carbon mobility systems. Hence, accelerating transition towards new and more sustainable and digital technologies are prerequisites for maintaining, or even increasing the global competitiveness of the European mobility ecosystem. Nevertheless, the ecosystem is currently grappling with profound economic challenges across all three of its main segments. Even prior to the Covid-19 pandemic, the industry was undergoing structural transformations concerning electrification, high CO2 emissions and pollutants. The Covid-19 crisis further compounded these existing challenges, leading to a staggering decline in sales of passenger cars by almost 24% in 2020[7] and a sharp drop in cruise ship orders, with new orders in Europe decreasing by around 90% in terms of Compensated Gross Tonne[8]. Consequently, this triggered cost-cutting measures from Original Equipment Manufacturers and suppliers due to severe liquidity problems[9]. While significant fiscal stimulus and EU recovery programmes helped mitigate risks, they have not completely resolved the issue at its full scale.

In recent years, the EU has witnessed a significant digital and green transition with the aim of shifting towards a more sustainable, low-carbon and resilient mobility system. On the one hand, the European Union (EU) has set ambitious targets to reduce greenhouse gas emissions by 55% by 2030, compared to 1990 levels, and achieve carbon neutrality by 2050[10]. To achieve these targets, the EU has, on the other hand, developed various policy frameworks to support the transition to a low-carbon economy, including the European Green Deal[11], the Sustainable and Smart Mobility Strategy[12], and the Alternative Fuels Infrastructure Directive[13].

The Sustainable and Smart Mobility Strategy, which was adopted in December 2020, aims to make transportation more sustainable, efficient, and accessible. It sets out various targets, including increasing the share of sustainable modes of transportation, such as walking, cycling, and public transport, to 75% of all urban transport by 2030. The strategy also aims to accelerate the shift towards zero-emission vehicles, with the goal of reaching at least 30 million zero-emission cars on the road by 2030. In addition to that, there are other complementary measures aimed at achieving decarbonisation. These measures include transitioning the fuels used by existing fleets to low-carbon options, establishing infrastructure to support the growing number of zero-emission vehicles and vessels, and implementing initiatives to stimulate markets for alternative fuels in the aviation and maritime sectors.

The development and adoption of electric vehicles (EVs) are crucial to achieving the transition to a sustainable and low-carbon mobility system. Europe has been a leader in the adoption of EVs, with Norway having the highest penetration of EVs in the world, followed by other European countries such as the Netherlands, Iceland, and Sweden. The European Union has also set targets to increase the number of publicly accessible charging points to one million by 2025 and three million by 2030. Moreover, the European

[7] Source ACEA and https://ec.europa.eu/docsroom/documents/48535
[8] From "Impact of COVID-19 on the Maritime Sector in the EU", EMSA: http://www.emsa.europa.eu/publications/item/4436-impact.html
[9] https://ec.europa.eu/docsroom/documents/48535
[10] https://climate.ec.europa.eu/eu-action/european-green-deal/2030-climate-target-plan_en
[11] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
[12] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12438-Sustainable-and-Smart-Mobility-Strategy_en
[13] https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32014L0094

Parliament approved the new CO2 emissions reduction targets and set the path towards zero CO2 emission for new passenger cars and light commercial vehicles in 2035[14].

Besides the challenges related to sustainability and digitalisation, the current landscape has been significantly impacted by disruptive events, such as the Covid-19 pandemic and the war in Ukraine, leading to substantial effects on the overall resilience of the ecosystem. Given the paramount importance of decarbonisation and digitalisation in the mobility industry, ensuring resilience and secure supplies of raw materials, batteries, and semiconductors becomes a critical aspect. As emerging technologies continue to shape the industry and supply chain disruptions persist, it is imperative to address new strategic dependencies with tailored measures. To achieve this, the European Commission intends to undertake various strategies. One of the primary approaches involves diversifying international supply chains and fostering international partnerships[15]. The guiding principle behind these initiatives is 'open strategic autonomy', which seeks to strike a balance between self-reliance and cooperation, ensuring an open, sustainable, and assertive trade policy. These proactive measures aim to support the green transition while promoting the development of responsible and sustainable value chains. By fostering collaboration and openness in trade policies, the Commission aims to overcome the challenges posed by current global events and create a resilient, adaptive, and future-proof mobility industry that aligns with sustainable development goals.

The automobile industry holds a pivotal role in spearheading both the digital and green transition in the entire ecosystem. However, companies from the EU, which have historically enjoyed a strong market position, are now encountering growing competition, particularly from Asian counterparts. To maintain its competitiveness, the European automobile sector must focus on adaptation and innovation, particularly in terms of providing affordable, efficient, and robust electric vehicles that are not only environmentally friendly but also manufactured sustainably. This approach is essential to remain competitive and keep pace with the increasing demand for eco-conscious and sustainable transportation solutions. However, while vehicle manufacturers can more easily adapt their product portfolios and are increasingly doing so, component suppliers may likely face more hurdles in repurposing or reconverting their existing activities towards new growth markets. The challenge can become particularly sensitive in certain regions of the EU with impacts on jobs.

In this respect, one of the crucial factors represents the development of cost-efficient high-performance batteries with significantly increased lifespan. The European Commission recognised the pressing need to establish a battery value chain within the EU and took decisive action by launching the European Battery Alliance (EBA) in 2017 and implementing the Strategic Action Plan on Batteries in 2018. Together with the Action Plan on Critical Raw Materials and the European Raw Materials Alliance, these initiatives target bolstering the EU's battery sector and fostering a sustainable mobility ecosystem. However, as the vehicle is not just a traditional car anymore but a digitally connected system, the industry must provide effective and secure connectivity solutions to enable seamless communication between vehicles and the infrastructure. Essential function plays the open data ecosystems, like for instance Catena X[16].

Deloitte[17] describes in particular three other revenue drivers in addition to the two traditional business models of automotive companies, vehicle production, and financial services, which are gaining rapidly in importance for transformation of the entire mobility ecosystem. One conceivable path would be for Original Equipment Manufacturers (OEMs) to retain their core competencies in vehicle production and specialise in the manufacturing of modular white-label concepts. This would result in a significant shift in the share of value

---

[14] https://www.europarl.europa.eu/news/en/press-room/20230210IPR74715/fit-for-55-zero-co2-emissions-for-new-cars-and-vans-in-2035
[15] https://ec.europa.eu/docsroom/documents/48535
[16] https://catena-x.net/en/
[17] https://www2.deloitte.com/content/dam/Deloitte/global/Documents/gx-deloitte-future-automotive-mobility-study.pdf

added from hardware manufacturers to suppliers of product-service (digital) solutions and thus facilitating the digital and sustainable transition of the entire eco-system. The second is the provision of mobility services, playing a key role in increasing sales in the future[18]. Offering a number of benefits to consumers, such as increased convenience, lower costs, and improved environmental sustainability, mobility services are increasingly becoming popular among consumers who are looking for convenient and flexible transportation options. Companies that are able to offer these services effectively are likely to see increased sales and growth in the future. Third, as vehicles become more connected and autonomous, they are capable of generating large amounts of data on everything from driving behaviour to vehicle performance. Automakers are expected to create safer, more efficient, and more personalised vehicles and thereby contribute to the transformation of the entire mobility ecosystem. However, it is increasingly important to balance the potential benefits of data collection with the need to protect user privacy and security.

In this report, we take on the challenge of examining the progress made in the green and digital transformation of the mobility ecosystem over time. Our analysis delves into the complexities of this development, which involves multi-level and dynamic changes across technological, economic, and social aspects. To begin with, we present a comprehensive overview of the green and digital technological landscape, identifying key positioning and challenges. Subsequently, we investigate the adoption and implementation of these technologies, emphasising the crucial of role of collaborative actions for establishing, for instance, standardised frameworks for open data ecosystems, hence facilitating the transition of the mobility ecosystem. Furthermore, we explore the current state of investments and funding in this sector, recognising the importance of financial support for driving the transformation. Additionally, as this transition may bring both opportunities and threats to the labour market, we conduct an in-depth analysis of the demand and supply of green and digital skills within the European market. Finally, we conclude our report by evaluating the environmental performance of the mobility ecosystem, focusing on its green initiatives and efforts towards sustainability. Throughout this analysis, we aim to provide a comprehensive and insightful view of the progress achieved in the transformation of the mobility sector while addressing the challenges that lie ahead.

[18]https://www.mckinsey.com/~/media/mckinsey/industries/automotive%20and%20assembly/our%20insights/disruptive%20trends%20that%20will%20transform%20the%20auto%20industry/auto%202030%20report%20jan%202016.pdf

2. Challengers of the industry status quo: green and digital technological trends

Key findings

The digital and green transformations pose many challenges to the mobility, transportation and automotive industrial ecosystem in the EU. These relate particularly to the adoption of new technologies that are necessary to safeguard competitiveness on the global market.

Due to the rise of China, but also positive developments in the USA and South Korea **European companies' share in the world patent applications have been constantly decreasing.** This shift reflects a **potential threat to Europe's technological and economic sovereignty in the domain of mobility solutions.**

However, when delving into particular technological domains encompassing digital and green progress, **in certain technological fields, European companies continue to assert their significant stature in terms of patent specialisation among the world's leading nations**. For instance, they share a prominent position in patenting battery-related technologies with China.

There has been also a s**harp increase in the number of startups in both green and digital technologies** active within the mobility industrial ecosystem over the period from 2010 to 2021.

However, trends over time suggest that there has been a shift towards digital startups that use AI, IoT (and related connectivity) technologies while the share of general software services decreased. Niche technologies such as blockchain are gaining an increasing momentum. On the other hand, the relative importance of digital technologies among startups such as robotics dropped significantly.

The **electric vehicle** sector in Europe is seeing a **rise in innovative startups**. By comparison, the dynamics of **startup activity in the field of autonomous vehicles has been very volatile**, with a significant decline in the number of developers and a decline in stock market valuation for self-driving car and truck startups since 2018. Besides **skill shortages, particularly with a view to engineers,** European startups have faced **investor reluctance caused by a lack of technological maturity and market readiness, regulatory uncertainties, and the Covid-19 pandemic.**

Despite the overall upward trajectory in startup growth since 2010, the statistics we have gathered reveal **a distinctively unstable pattern in the emergence of new enterprises within the Mobility as a Service (MaaS) sector** from 2016 onwards. However, some new and innovative business models based on **data-driven servitisation combined with the high demand for combined and sustainable solutions have opened new windows of opportunities for future startups** in Europe.

Within the spectrum of autonomous vehicles, battery technology, and electric vehicles, Europe's position in terms of **unicorn startups in mobility sector is notably marginalised compared to the leading nations**. Notably, the European Union emerges as a **frontrunner solely in the domain of Mobility as a Service**, while lagging significantly behind the United States and China across other vital areas, like for instance autonomous vehicles, battery and electric vehicles.

In recent times, there has been a notable shift towards embracing digital and green mobility solutions as a direct response to mounting environmental concerns. This transformation stems from the imperative to harness technological advancements to create transportation systems that are both efficient and sustainable. Moreover, the increasingly competitive market landscape has significantly influenced companies' differentiation strategies, compelling them to offer more eco-friendly and technologically advanced product and service solutions.

New digital and green mobility technologies represent crucial enablers of the required transition in the ecosystem. **Digital technologies,** on the one hand, **are critical in facilitating and optimising transportation** by enabling vehicles to be more efficient and environmentally friendly. **They help optimise routes, reduce fuel consumption, improve safety, and reduce congestion.** Digital technologies also allow the integration of different modes of transport into a single, seamless service. Data collected from digital technologies can be used to improve route planning, reduce congestion, and identify areas for investment in sustainable transport infrastructure. Mobility as a Service (MaaS) platforms and apps can help reduce the need for private car ownership and encourage the use of sustainable transport. Blockchain technology improves the security, transparency, and efficiency of transactions, while electric vehicles rely on digital technologies for efficient charging, managing electricity demand, and using renewable energy sources.

Recent trends in technologies for green mobility, on the other hand, include **advancements in battery technology, the increasing popularity of hydrogen fuel cells, the use of lightweight materials in vehicle manufacturing, the development of vehicle-to-grid (V2G)** technology, and the potential of autonomous and connected vehicles to revolutionise green mobility. Renewable energy sources such as solar and wind power are also being used to power green vehicles and are expected to assume an increasingly important role for the ecosystem in the future.

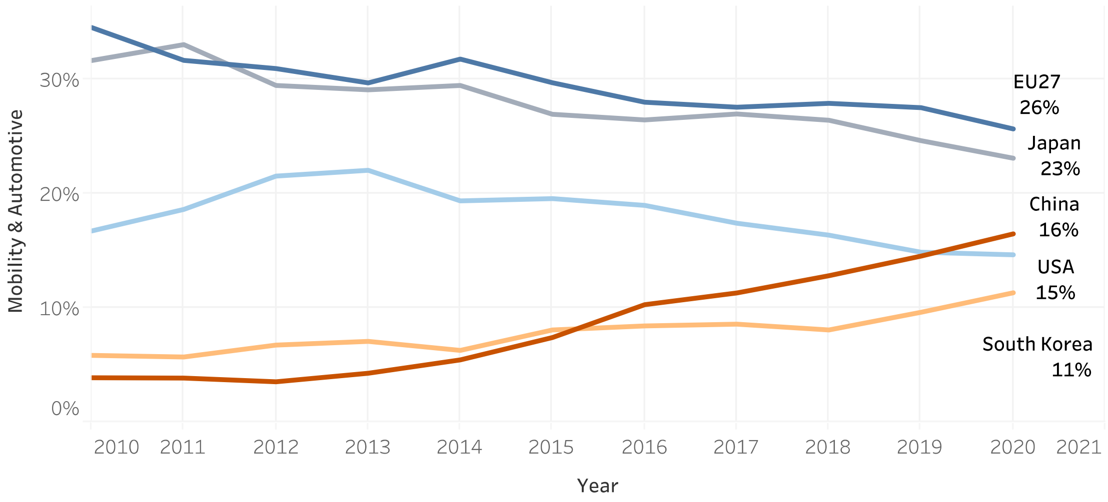
To track technological developments with relevance for the ecosystem and its green and digital transformation, we analysed on the one hand patenting activities[19] related to the specific sectoral activities adopting patent-based classifications and on the other hand technology startups and scaleups challenging the current status quo in the industry, to complement the analysis.

2.1. Technological positioning of the EU mobility industrial ecosystem and key challenges

Figure 3 shows the main trend in the share of world patent applications in the ecosystem. The graph illustrates a **general decrease in the share of patent applications by the European mobility industrial ecosystem** in all worldwide patent applications in this domain. While 15 years ago almost 40% of all patents in the ecosystem came from the EU27 countries and only a small share from China and South Korea, this share has been significantly changing due to the significant technological catch-up of Chinese and South Korean companies which resulted in increasing patenting activities in non-European countries in recent years. This trend is caused especially by the following factors[20,21]. First, the market's growth potential, characterised by the high demand for transportation in these countries, has created opportunities for companies to develop and deploy new technologies that can improve mobility and transportation services. Second, by the fact that governments, venture capitalists, and other investors have provided substantial support to companies in the ecosystem, enabling them to develop and commercialise new technologies. Finally, Asian countries have implemented policies to support the growth of their domestic mobility industries, which has encouraged companies to invest in R&D and to file for patents to protect their intellectual property[22,23].

[19] Our analysis was based on 'transnational patents' (Frietsch/Schmoch, 2010) (i.e. PCT/WIPO filings or direct applications at the EPO, excluding double counts) and was conducted on an extended version of the EPO's Worldwide Patent Statistical Database that Fraunhofer ISI implemented locally. Technologies-relevant-to-ecosystems were defined based on search that refer to patent classifications (IPC) and/or use keywords to identify relevant applications across classes.
[20] Frost & Sullivan (2020): Analysis of the Chinese Mobility Market, Forecast to 2025
[21] https://english.news.cn/20221209/4e24e656a3ec425ba4f7389101c03336/c.html
[22] https://www.oecd.org/korea/korea-policy-priorities-for-a-dynamic-inclusive-and-creative-economy-EN.pdf
[23] https://merics.org/sites/default/files/2020-04/Made%20in%20China%202025.pdf

Figure 3: Trends in the EU27 share of patent applications in world total in the field of the mobility industrial ecosystem in 2010-2020 and comparison of global shares in 2020



Source: Fraunhofer calculations, Patstat

A more detailed patent analysis was conducted with a particular focus on the digital and green transition. In this process, our analysis of digital and green patent applications related to the ecosystem that was based on the 2022 PATSTAT database as well, but exclusively focused on WIPO applications. Both the industrial ecosystem and specific technologies were delineated by a set of Cooperative Patent Classification (CPC) categories. By using this approach, we were able to capture representatively the patenting activity in the entire ecosystem and observe trends in distribution and development with a view to specific technologies. The classification of green transition technologies builds upon the OECD green patents classification that we augmented by including additional technologies particularly relevant to the ecosystems. The identification of digital transition technologies builds on earlier work on Industry 4.0 (Balland and Boschma 2021) and includes additional technologies particularly relevant to the ecosystem.

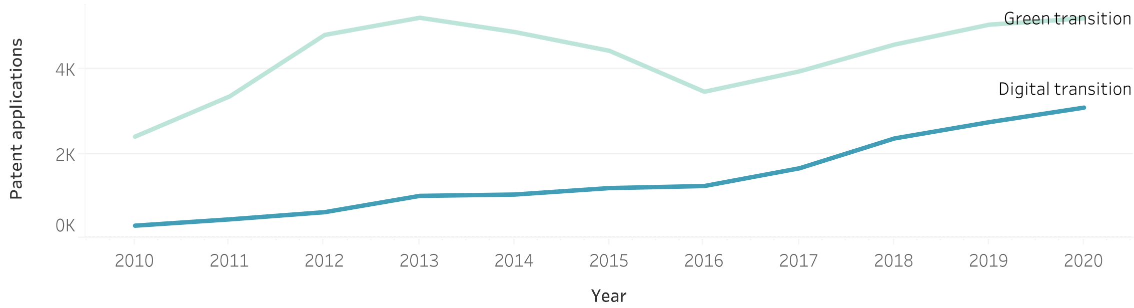
Figure 4 shows the number of green and digital patent applications over the years from 2010 onwards. With respect to **digital technologies**, which are characterised by a wide implementation scope[24], there is a **constantly growing trend in patent applications**. On the contrary, while there was a **fast-increasing trend in patent applications of green transition relevant technologies up until 2013, this surge in application was followed by a marked slowdown and decline until 2016. This slump in patent applications is likely to have been** caused, i. a., **by long-term policy uncertainty in terms of green transition that was prevalent that this time**, and which may have deterred companies from committing resources to green technologies and mobility. However, increasing public awareness and demand combined with global trends like Paris Agreement on climate change, signed in 2015, may have increased the interest in green technologies and spurred more patenting activity in this area since 2016.

Additionally, the analysis shows a decline in development of both considered technology groups since 2019. This can in part be explained by Covid-19 pandemic and its generally negative effect on innovation in many segments including also mobility. The pandemic led to a shift in priorities and focus, with many companies placing greater emphasis on short-term solutions to address the immediate challenges presented by the pandemic, such as ensuring the safety of their employees and customers and maintaining their financial stability, rather than longer-term research and development activities[25]. This shift in priorities, coupled with the economic uncertainty and financial pressures caused by the

[24] https://www.dpma.de/english/services/public_relations/press_releases/20220309.html
[25] https://www.mckinsey.com/capabilities/risk-and-resilience/our-insights/covid-19-implications-for-business

pandemic, has exacerbated a decrease in patenting activity in the entire ecosystem that was in part evident before, as is evident from other studies.

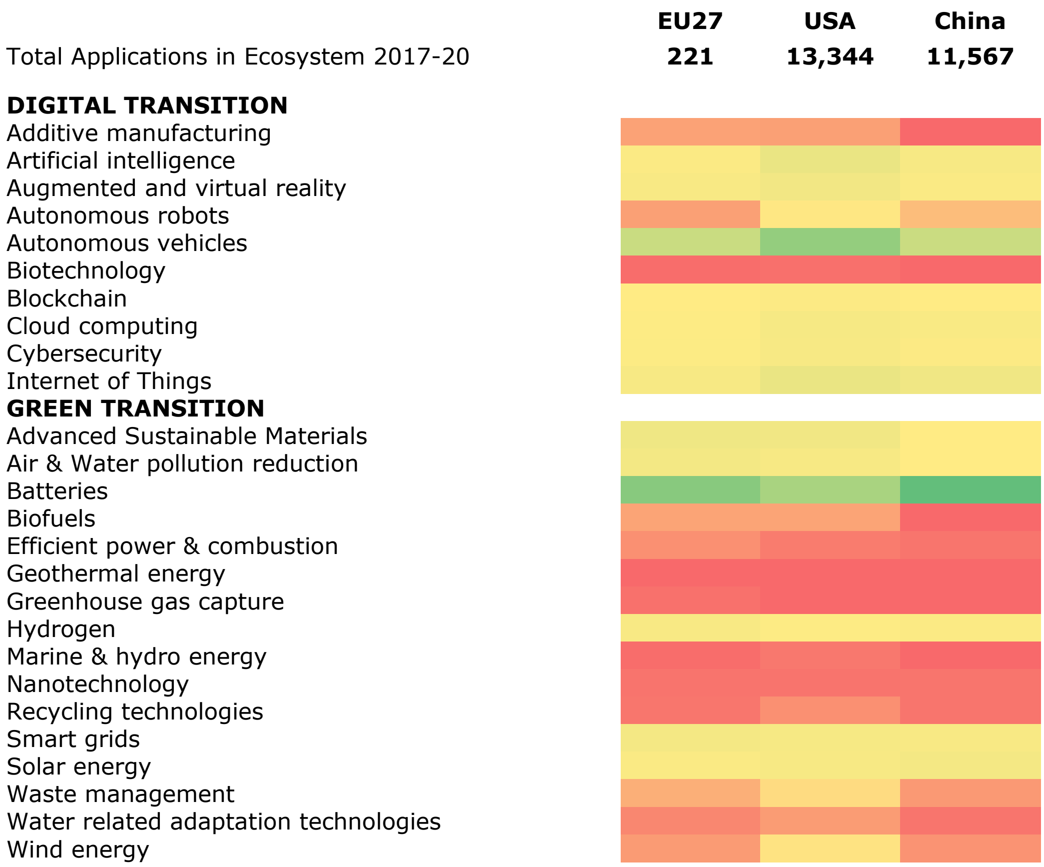
Figure 4: Trends over time in digital and green transition related patent applications connected to the mobility industrial ecosystem



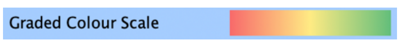
Source: Balland, 2022 based on PATSTAT

To analyse the relevance of single technologies within the two contexts, digital and green transition, and thus to shed light on technological trends affecting the ecosystem on a global scale, we researched into patent distributions. We analyse thereby the share of patent applications of EU27, China and USA in world total.

Figure 5: Patent specialisation in digital and green transition related technologies within the mobility ecosystem



Source: Balland, 2022 (specific technologies); Fraunhofer ISI, 2022 (total ecosystems) based on PATSTAT

Legend: low to high shares 

From Figure 5 we can see a high relevance of digital innovation in the area of **autonomous vehicles**, particularly in the EU27 and USA. Although China is investing heavily in research and development in the field of autonomous vehicles, the challenges with standards and regulatory environment, intellectual property protection and market demand have all contributed to Chinese lower patenting activities[26]. Due to high relevance of the management of electric grid, particularly its reliability, efficiency and security, the smartification has been playing an increasing role in this area, particularly connected with the very current price increases and system stability issues. By using smart grid technology for deploying of intelligent charging systems, the mobility sector can help balance the energy demand of EVs with the availability of renewable energy sources, while ensuring the stability of the grid. This relevance of **smart grid technologies** is evident also in patent statistics with the highest share of European innovation. In contrast, facilitated by a strong research and development ecosystem for innovation in wide application areas of **artificial intelligence (AI)** combined with a supportive legal and regulatory environment, the USA takes the leading position in patent applications considering AI and closely related technologies, like autonomous robots and quantum computers, despite the rather minor differences to the EU27. The situation is similar also in the field of **cloud computing** technologies.

With respect to the role of specific digital and green transition technologies for the mobility ecosystem, Figure 5 illustrates a to be expected focus on **batteries**, that is in relative terms even more pronounced in China and Europe than it is in the US. The US, in turn, display the strongest specialisation in the second main area of activity, autonomous vehicles.

In general, the US mobility ecosystems displays stronger specialisation in **technologies related to the digital transition** than its European and Chinese counterparts, which becomes particularly obvious in the field of autonomous robots. That said, the level of activity in digital fields but autonomous vehicles remains quite limited.

Likewise, battery technologies are the only real area of inventive dynamics with a view to **technologies related to green transitions**, with some level of activity also detectable for advanced sustainable materials, air & water pollution reduction, hydrogen, smart grids and solar energy, all of which confirms anecdotal knowledge about the sector.

While the European mobility ecosystem thus does not display a very characteristic profile, its **patent level remains highest among all three ecosystems** considered. Despite the substantial dynamism in China and the US, the overall level of mobility related patenting in Europe remains about two times as high as in either of the other ecosystems, at least when considering globally relevant patents applied through the WIPO's PCT process.

Thus, **European inventors continue to file higher numbers of patent applications on mobility related issues than their Chinese and US competitors**, both generically as well as in the ecosystem's two key fields of technological effort: batteries and autonomous vehicles.

2.2. Mobility tech startups and scaleups challenging the industry

Technology startups represent key building blocks in the transition towards a more green, digital and resilient economic model. Entrepreneurial activity helps accelerating the diffusion of technologies in industrial ecosystems and startups that provide green and digital mobile solutions are relevant indicators of how the industrial ecosystem is transforming itself to reach environmental sustainability objectives. Mobility tech startups are challenging the traditional players of the mobility industries and in particular digital tech companies are increasingly become a competition in particular in the field of data-based mobility solutions[27]. In this section, the analysis of technological and innovative startups is based on tech startups and companies active in the mobility industrial ecosystem that have been sourced from the Crunchbase and Net Zero Insights startup

[26] KPMG (2022): Levelling Up: China's race to an autonomous future.
[27] See also the analysis of Deloitte (2022). The future of automotive mobility to 2035 How mobility providers should adapt to profit from tomorrow's value chain

databases. The examples of startups are also used to structure the main green and digital technological domains that impact the industry.

By investigating the evolution of companies in the ecosystem created over time, the first observation to make is the sharp increase in the number of mobility tech startups, that focus on aspects of the digital or green transition as core part of their value proposition, i.e. business model, active within the industrial ecosystem over the analysed period (see **Error! Reference source not found.**). This development indicates a progress towards t he green and digital transition by an **increasing share of new solution providers emerging** within the ecosystem and enabling the shift to a low carbon and circular economy model. Growing demand for green and digital solutions, which results from increasing concerns about air pollution and climate change[28], represents a significant market opportunity for startups in the ecosystem. At the same time, the increasing number of startups can be attributed to the strong technology push policy characterised by good availability of funding as well as favourable regulatory environment[29]. The results show a stable and **increasing trend in number of new players entering the market to develop electric vehicles, autonomous driving technology, and other mobility services and innovations**.

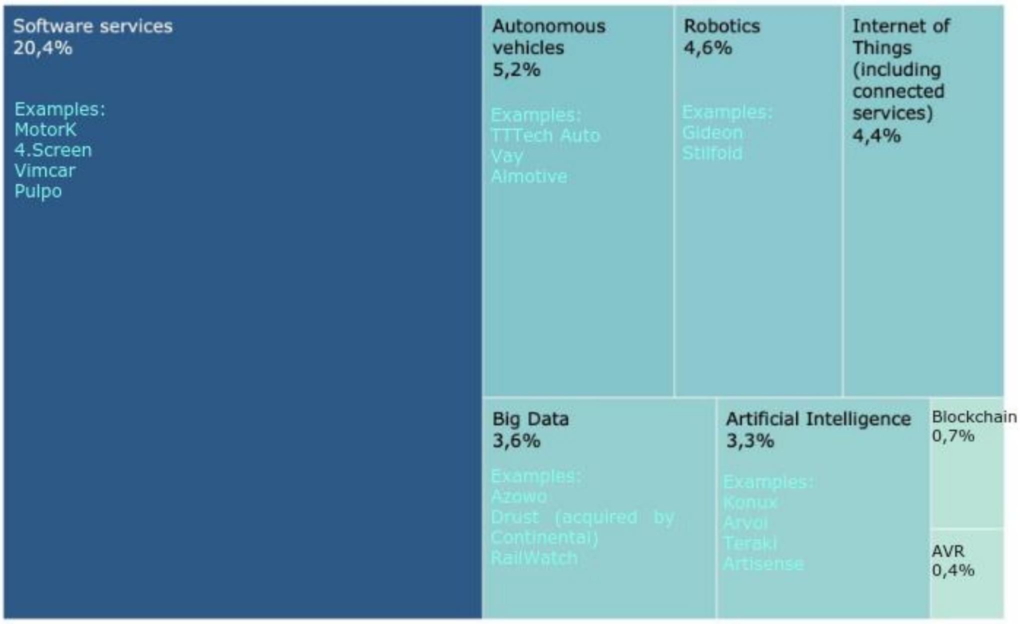
2.2.1. Digital mobility tech startups

We further analysed digital mobility tech startups that foster the digital transformation of the mobility ecosystem. Figure 6 presents the type of technologies that digital mobility tech startups base their services on. This analysis follows the extraction of Crunchbase and Net Zero Insights data set of 4 980 active startups in the ecosystem founded between 2010 and 2022. The results show that software services coupled with cloud computing, data analytics, Internet of Things, artificial intelligence, and blockchain technologies play a crucial role. Related to this, McKinsey estimates that the value share of software integrated in vehicles will increase to as much as 30% of the total value of the car by 2030[30].

Moreover, the typology of digital mobility tech startups has been compared between two time periods notably 2000-2007 and 2015-2021 in order to reveal trends. Figure 7 presents the share of digital mobility tech startups per technology within the total number of mobility tech startups in the specific periods. Trends over time suggest that there has been a shift towards digital startups that use AI, IoT (and related connectivity) technologies while the share of general software services decreased. Niche technologies such as blockchain are gaining an increasing momentum. On the other hand, the relative importance of digital technologies among startups such as robotics decreased. The picture also hides the shift towards mobility tech startups that address the green transition and are presented in the next section.

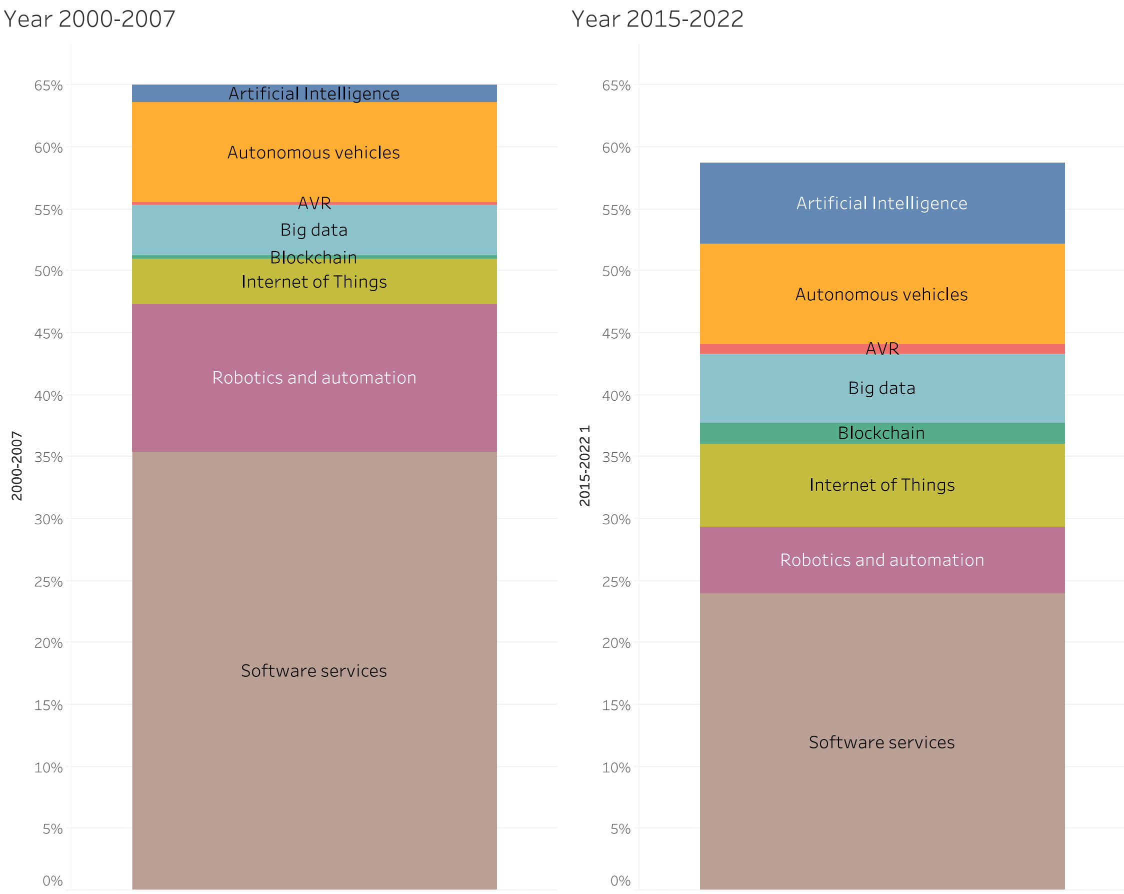
[28] https://joint-research-centre.ec.europa.eu/jrc-news/green-and-digital-future-7-insights-strategic-foresight-2022-06-30_en
[29] https://ec.europa.eu/commission/presscorner/detail/en/ip_22_7437
[30]https://www.mckinsey.com/~/media/mckinsey/industries/automotive%20and%20assembly/our%20insights/a%20long%20term%20vision%20for%20the%20european%20automotive%20industry/race-2050-a-vision-for-the-european-automotive-industry.pdf

Figure 6: Type of technologies and services linked to mobility tech startups with some examples



Source: Technopolis Group based on Crunchbase, 2023

Figure 7 Type of technologies and services within mobility tech startups



Source: Technopolis Group based on Crunchbase, 2023

Software-based mobility services

The largest share of digital mobility tech startups focuses their business model on **software-based services**, encompassing cloud technology. However, this proportion has markedly decreased from twenty years ago, during which one in every three newly established companies followed this approach. This shift can be attributed, in part, to the maturation of certain conventional software solutions. These solutions have tended to become standardised or integrated into larger platforms, diminishing the scope for startups to offer distinctive features and complicating their market differentiation endeavours. Moreover, the mobility sector, spanning ridesharing, electric vehicles, autonomous transportation, and related technologies, has experienced a substantial surge in startup ventures over recent years. This heightened influx of competitors may potentially result in market saturation, thus amplifying the challenges encountered by fledgling startups striving to attract attention and secure a customer base. Notably successful are companies that present holistic solutions for the entire mobility ecosystem, such as those catering to multimodal transportation needs. An illustrative instance of this is the INSTANT System[31].

Internet of Things and connected mobility services

Unlike traditional software services, the incorporation of **Internet of Things (IoT)** technologies is witnessing a growing trend among startups within the mobility sector in the recent years. This importance is also emphasised by the anticipated surge in IoT-connected devices, projected to rise from 40 billion in 2023 to a remarkable 49 billion by 2026.[32] The European domain is unequivocally embracing IoT, with a substantial number of organisations capitalising on the capabilities of cloud infrastructure and signalling their commitment to investing in IoT solutions. This upsurge in adoption results in a deluge of data processed at the network edge. This strategic approach not only minimises communication, storage costs, and energy usage but also paves the way for the application of machine learning and artificial intelligence. These technologies are instrumental in deciphering intricate data patterns with tangible real-world implications. This progress creates an opportune environment for companies in the mobility ecosystem. The ranks of such startups in both areas of IoT and Big Data have been consistently expanding, particularly within the last half-decade, as depicted in Figure 7. A noteworthy example is Cubic Telecom[33], an innovative company that has introduced the PACE platform—a cutting-edge IoT-connected software solution—tailored for automotive, agriculture, and transport manufacturers. This platform has garnered global recognition and patronage, counting industry giants like Audi, Microsoft, Kymeta, Panasonic Automotive, Volkswagen, CNH Industrial, Skoda, e.GO Mobile, and Arrival among its users. The convergence of IoT, sensor fusion, and allied connectivity technologies has cultivated fertile ground for the evolution of telematics, data analytics, and infotainment features within vehicles. This transformation has unlocked an array of novel functionalities embedded within automobiles. The practical applications in this domain facilitate services such as predictive maintenance, extended range optimisation, event detection, and comprehensive data collection campaigns, all tailored for connected and autonomous vehicles.

Artificial Intelligence

Artificial Intelligence technologies play a crucial role for smart mobility products and services[34]. From 2020 to 2022, there was a remarkable development in startup companies dedicated to AI advancements. The most recent instances of AI ventures develop primarily machine learning and chatbot innovations, with a strong emphasis on improving the synergy between humans and machines. In recent times, there has been a remarkable upsurge in the share of mobility startups whose products and services incorporate AI (see

---

[31] https://instant-system.com
[32] https://digital-strategy.ec.europa.eu/en/policies/internet-things-policy
[33] https://www.cubictelecom.com
[34] https://op.europa.eu/en/publication-detail/-/publication/3b2bb4f5-1699-11ec-b4fe-01aa75ed71a1/language-en/format-PDF/source-231842358

Figure 7). As this trend gains further traction [35], the symbiotic relationship between AI and the mobility sector holds the potential to not just streamline daily commutes but also lay the groundwork for a more sustainable and interconnected future in Europe. Notable instances of this trend include DeepSea Technologies[36], a company offering AI-powered vessel optimisation for the maritime industry, and Compredict[37], which furnishes comprehensive vehicle insights by utilising AI-driven virtual sensors that tap directly into onboard vehicle signals.

Autonomous vehicles

In Europe, the trajectory of **autonomous vehicle** development exhibits a volatile trend, displaying a surge in developer engagement up to 2018, followed by a swift downturn in recent years. This oscillation reflects the ongoing developmental phase of autonomous driving technologies. Aspiring startups in this domain must confront the considerable expenses associated with development, posing a challenge unlike the more favourable conditions found in mature fields such as electric vehicles or mobility as a service. Though expectations for widespread adoption of Level 5 autonomous driving are tempered, Level 4 remains a target due to its technical feasibility. However, even at this level, the occurrence of errors remains an impediment to rapid integration of technologies in the existing mobility systems. Investor enthusiasm for quick returns has led some to divert their investments towards more promising ventures. The Covid-19 pandemic has exacerbated uncertainties around revenues and profits, fostering investor reluctance to back autonomous vehicle startups. Furthermore, European startups in this technological field face additional hurdles, contending with scarcity in funding and skilled labour, mirroring a global trend. Crunchbase's analysis underscores the collective decrease of USD 40 billion in stock market valuation for self-driving startups in the past two years. Despite those challenges, there are some cases of successful startups in this segment, like for example Einride, Vay, Aimotive and TTTech Auto and EasyMile. Einride[38] is a leading freight technology company providing digital, electric, and autonomous shipping. Vay[39] is a teledriving company that aims to launch a unique, affordable, and sustainable door-to-door mobility service. With its first service, Vay plans to remotely bring and remotely park electric cars for its customers. Customers order an electric vehicle via the Vay app. A teledriver brings the car directly to a valid pick-up location for the customer – remotely controlled from the teledrive centre. Upon arrival of the car, the customer physically drives themselves to their destination. Once the customer has arrived at their destination, a teledriver takes over the vehicle once again at a valid drop-off point. This eliminates the time-consuming search for a parking space. Aimotive[40] is one of the largest independent teams in the world working on automated driving technologies. TTTech Auto specialises in safe software platforms for automated driving and beyond, applicable in series production programmes. EasyMile[41] is a high-tech startup specialised in providing both, software powering autonomous vehicles and smart mobility solutions.

Blockchain

Finally, by increasing the transparency and trust, **blockchain technology** brings secure identity to vehicles and infrastructure. As the era of advanced autonomous vehicles ushers in an era of automation, blockchain's smart contracts come to the fore, streamlining operations and facilitating frictionless transactions. This, in turn, mitigates challenges such as overreliance on credit cards. Startups in the EU27 are capitalising on tokenisation to establish connections between public and private service providers within the mobility ecosystem and the decentralised realm of finance, all while maintaining security and

[35] https://op.europa.eu/en/publication-detail/-/publication/3b2bb4f5-1699-11ec-b4fe-01aa75ed71a1/language-en/format-PDF/source-231842358
[36] https://www.deepsea.ai
[37] https://compredict.ai
[38] https://www.einride.tech
[39] https://vay.io
[40] https://aimotive.com
[41] https://easymile.com

compliance. This includes the implementation of tokenised payments and loyalty incentives aimed at reducing carbon emissions. For instance, a prime illustration of the convergence of blockchain technology, decentralised finance (DeFi), and tokenisation is found in MobiFi[42]. This visionary initiative is constructing a sustainable and impartial mobility ecosystem, integrating a diverse array of services like e-scooters, ridesharing, electric vehicle charging, parking, buses, and metros onto a unified platform. The overarching goal is to empower companies to optimise their operations, delivering a seamless and convenient transit experience to their users.

2.2.2. Environmental startups in mobility

On the other hand, considering green technologies, companies providing technological solutions in the area of electric vehicles represent the largest group of startups analysed in the full mobility startup data set, with around 12%. Interestingly, all other sustainability relevant technology groups, for instance **battery, recycling** and **advanced materials**, are represented with significantly smaller shares of around 1% of all considered companies. One good example here is **recycling and circular economy**, which is known as one of the main drivers of global sustainability; hence, one would expect a much higher share of new companies providing novel solutions in this area. Similarly, despite the crucial role of technologies advancing **energy efficiency** in companies, for example because of current disruptions in the global energy supply chains and rapidly increasing energy costs, our statistics show a surprisingly low share of startups focusing on those technologies in their business models in the EU, only at around 0.3%.

Electrification of mobility

Inspired by a new era in mobility and decreasing costs of building electric vehicles compared with their fossil-fuel-guzzling forbears, **the number of innovative startups in the mobility and automotive area has been growing rapidly** as demonstrated by startup data. Overall, the combination of policy support, technological innovation, environmental concerns, and a strong entrepreneurial culture has created a favourable environment for startups in the electric vehicle sector in Europe, leading to a steady increase in the number of new companies entering the market. The electric vehicle sector is still in its early stages, and there is a lot of room for innovation and technological development. European countries have been implementing policies to promote the adoption of electric vehicles and thereby boost the demand, including tax incentives, subsidies and grants, stricter emissions regulations, and even public procurement [43]. This has created a favourable environment for startups in the electric vehicles sector, as they can benefit from government support directly, on the one hand, and take advantage of growing demand for electric vehicles, on the other. Consequently, alongside traditional players in the industry, like for example OEM or well-known suppliers, these innovative companies play a significant role for the green and digital transition. They are not only enablers and accelerators of transition in electric mobility, but they also advance the shift to sustainable mobility by, e.g., developing new battery technologies, charging infrastructure, or new materials and technologies. Some good examples are companies like IONITY, TIER Mobility and Voi. IONITY[44] has built a highway-charging network across Europe, which is open to electric vehicles of all brands accelerating thereby the e-mobility and long-distance traveling. TIER Mobility[45] is a micro-mobility company providing sustainable ride-sharing solutions. Voi[46] is also a micro-mobility startup that provides electric scooters for last-mile transportation closing thereby the circle of intermodal personal mobility.

[42] https://mobifi.io/
[43] European Environment Agency (2016) Electric vehicles in Europe. EEA report No 20/2016
[44] https://ionity.eu
[45] https://www.tier.app/en
[46] https://www.voi.com

Mobility as a service fostering the green transition

In Europe, there is a fast-growing trend of Mobility as a Service (MaaS), as an increasing number of customers seek combinations of alternative transportation modes that can ideally cater to their requirements and preferences, such as in terms of cost-effectiveness, accessibility, and eco-friendliness. Considering the trend in startups addressing with their business models the MaaS area, there is a general increase in the number of newly established companies. The market for innovative business models in Europe is seeing new opportunities due to the growth in demand for electric and shared mobility[47], as well as the increasing popularity and maturity of digital platforms that provide comprehensive solutions for users[48]. This trend is fuelled by the rising demand for sustainable and cost-effective mobility options, which is driving the growth of the market[49].

Despite the overall upward trajectory in startup growth since 2010, the statistics we have gathered reveal **a distinctively unstable pattern in the emergence of new enterprises within the Mobility as a Service (MaaS) sector from 2016 onwards** (see **Error! Reference source not found.**). The principal attributions for this p henomenon can be attributed to demand-side factors and the intricate nature of the MaaS system. In contrast to private automobile usage, MaaS can appear considerably more complex. The intricacies of navigating diverse service providers, transportation modes, and payment systems can be overwhelming for users. Moreover, the availability of MaaS services is not consistently reliable, resulting in uncertainties when planning journeys. Additionally, the success of MaaS is most pronounced in major urban centres with abundant transportation alternatives and robust demand. However, within these urban settings, service providers encounter intense competition, which in turn can complicate differentiation efforts and the management of costs. Conversely, in smaller towns and rural regions, the demand for MaaS services might not suffice to cover the fixed operational costs, rendering expansion into these locales financially precarious.

Over and above the intricacies related to demand and operational complexities, the regulatory landscape for MaaS services is a mosaic of varying rules and guidelines, differing from one jurisdiction to another. Restrictions on vehicle usage, mandates for designated parking spaces dedicated to MaaS services, and collaboration requirements with public transportation systems collectively contribute to the intricacy of the operational environment. The absence of standardised policies can obstruct the growth of MaaS and generate uncertainties for both service providers and users.

The digitised nature of MaaS services introduces its own array of difficulties, particularly concerning data privacy. Although customers may harbour apprehensions about the security of their personal information, a more significant concern revolves around data sharing between Mobility Service Partners and public transport providers. The cooperation indispensable for the triumph of MaaS mandates data exchange, yet apprehensions surrounding control and potential dominance by tech giants such as Google loom large. Endeavours to normalise data interfaces for MaaS through National Access Points (NAPs) have encountered varying degrees of success. While the European Union endeavours to standardise MaaS integration, certain member states, like Germany, have not wholeheartedly embraced these regulations. This lack of alignment can obstruct the interoperability of MaaS platforms and hinder cross-border mobility.

Lastly, the acceptance of MaaS services is far from uniform, varying from city to city, and encountering resistance is not an uncommon occurrence. An illustrative instance is the situation in Paris, where e-scooters recently faced prohibition due to safety and urban clutter concerns. This underscores the significance of comprehending local dynamics and addressing specific issues in order to cultivate an environment conducive to the flourishing of MaaS.

---

[47] https://www.statista.com/outlook/mmo/shared-mobility/europe
[48] https://digital-strategy.ec.europa.eu/en/policies/technologies-digitalisation-transport
[49] Deloitte (2017): The rise of mobility as a service - Reshaping how urbanites get around

As the journey towards realising the full potential of MaaS continues, stakeholders must acknowledge and navigate these complexities. Addressing issues of simplicity, cost, density, policy, digitalisation, legality, and acceptance will be critical in shaping the future of urban mobility. A collaborative effort between public authorities, private companies, and the community is essential to develop a MaaS ecosystem that is both efficient and sustainable.

2.2.3. Scaleups and unicorns

The landscape of mobility has undergone a remarkable overhaul in recent times, primarily instigated by the emergence and widespread growth of unicorn startups. These inventive enterprises, valued at over $1 billion, have played a central role in reconfiguring the movement of people and goods within and between urban areas. Leveraging technological advancements such as the Internet of Things (IoT), Artificial Intelligence (AI), and data analysis, the unicorn startups in the mobility sector have introduced ground-breaking solutions. These include platforms for ridesharing, electric and self-driving vehicles, options for compact modes of transport, and comprehensive integrated transportation services. These startups have not merely disrupted traditional transportation models but have also paved the way for more environmentally friendly, efficient, and interconnected mobility systems.

Our analysis on mobility unicorns presents a comprehensive assessment derived from the analysis of Crunchbase data for the year 2022. The results of our analysis (see Figure 8) underscores a distinctive landscape in terms of global unicorn startup distribution. Notably, the European Union emerges as a frontrunner solely in the domain of Mobility as a Service, while lagging significantly behind the United States and China across other vital areas. Within the spectrum of autonomous vehicles, battery technology, and electric vehicles, Europe's position is notably marginalised compared to the leading nations. Of particular interest is the electric vehicle sector, wherein Europe's representation of merely seven unicorn companies stands in stark contrast to the United States' 17 and China's 27 such companies. This data serves to underscore the prevailing market vulnerability of European startups in relation to their dominant counterparts in the United States and China.

Figure 8: Comparison of unicorns globally

Number of unicorns in:	EU27	USA	China
Autonomous vehicles	2.00	7.00	11.00
Battery	3.00	7.00	9.00
Electric vehicles	7.00	17.00	27.00
Mobility as a service	32.00	28.00	17.00

Source: Technopolis Group based on Crunchbase, 2022

3. Uptake of green and digital technologies and business models

Key findings

The results of a representative business survey conducted with representatives of 355 SMEs from the mobility, transport, and automotive ecosystem show that **both the green and digital transition of SMEs in the ecosystem have gained pace, yet remain at relatively low diffusion levels**.

For both dimensions of the twin transition, about 45% of the respondents indicated to have increased their investments significantly in the past five years. The detailed analysis of the uptake of green technologies, green business models, and environmental standards, as well as digital technologies, however, reveals **low adoption rates for any specific cluster of green and digital technologies, type of green business model, or environmental standards**.

These findings indicate that **rather than** a perceived **lack of relevance, lack of strategic focus**, or **missing investment capabilities** of the SMEs, **other factors** appear to **hinder a more widespread uptake and diffusion of the green and digital twin transition among the SMEs in the mobility ecosystem**.

In respect to green technology uptake, SMEs in the mobility ecosystem have been most active in the implementation of energy saving technologies, circular initiatives, as well as renewable energy sources.

Complementarily, **the most frequently employed sustainable business models aim at extending the product life cycles, provide mobility services, and resource efficiency**. While the adoption rates of any single type of green business model is low, it can be concluded that in total a sizable share of the surveyed SMEs is engaged, to a certain degree, in at least one of type of sustainable business model.

While up to a third of all surveyed companies reports to have obtained a type of environmental certification in the past, there appears to be a negative trend in the issuance of ISO 14001 across the mobility ecosystem in recent years, closely mimicking a more general negative trend across all European industrial ecosystems.

A detailed analysis of the uptake of digital technologies shows that the **most relevant digital technologies for SMEs in the mobility sector pertain to online platforms, cloud technologies and services, as well as general and specific IT software**.

Further analyses of digital spotlight technologies including AI, IoT, AVR, and robotics technologies, reveal their most frequent use cases across the mobility ecosystems value chains.

Potential synergies between digital technologies and green use cases have, so far, only rarely been realised for most of the analysed spotlight technologies. Only for AVR technologies were sustainability-focused use cases implemented by a significant share of technology adopters.

With the objective to monitor the status quo of the uptake of green and digital technologies and business models across all European industrial ecosystems, the EMI survey, a large-scale business survey, has been conducted. The EMI survey was implemented based on a Computer Assisted Telephone Interviewing (CATI) approach. The final sample included 3 900 companies across all industrial ecosystems. Out of this final sample, **355 interviews were conducted with firms active in the mobility, transport, and automotive ecosystem**, henceforth the mobility ecosystem. The main fieldwork was conducted between 15 January and 15 May 2023.

The survey focuses on SMEs, as they are key players across all industrial ecosystems, and hence play important roles for the prosperity of the European Union's member states. Furthermore, they also hold a significant position in the ecosystem studied in this report, as they comprise up to 99.7% of the firms active in the mobility ecosystem.

A prerequisite for each interview was to have a respondent with adequate capacities and knowledge to answer the questionnaire (for more details please see the methodological report of the project). Accordingly, the survey respondents are comprised of a mix of senior representatives from micro-enterprises (less than 10 employees), small enterprises (10-50 employees) and medium-sized enterprises (50-250 employees). In terms of geographical coverage, the survey has a balanced coverage of all EU countries and is hence representative for the entire European Union. Furthermore, the survey was designed to complement existing surveys, such as the "Flash Eurobarometer 498 on SMEs, green markets, and resource efficiency[50]", and the "ICT-usage in enterprises survey"[51], in terms of temporal and thematic coverage, by adopting a similar questionnaire design.

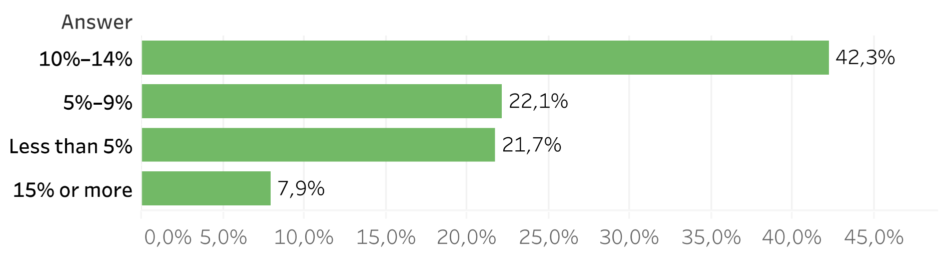
3.1. Green transition of SMEs in the mobility ecosystem

To paint a holistic picture of the status quo and importance of the green transformation for SMEs in the European mobility ecosystem, the survey respondents were asked whether they **had increased their investments dedicated to the green transition** and environmental sustainability in recent years. **45% of the respondents indicated to have increased their investments during the past five years**; indicating that almost every second SME active in the ecosystem has intensified its efforts to actively participate in the green transition.

Further enquiry into the funds dedicated to the green transition (i.e., percentage share of average annual revenue invested in green technologies, etc.) revealed **that a large share (42.3%) of the respondents had re-invested between 10-14% of their annual revenue in projects related to the green transition** (i.e., green technologies, sustainable business models, or meeting environmental standards (see Figure 9)).

These results emphasise the important role the green transition has played in the investment strategies of the SMEs active in the European mobility ecosystem in recent years. The findings are even more striking when we consider these increased investments against the backdrop of the unfavourable socio-economic conditions and uncertainties in recent years, which had significantly decreased these firms' financial turnover[52,53], subsequently adversely impacting their investment capabilities as well.

Figure 9: Share of revenue invested in green transformation by SMEs in the mobility, transport and automotive industrial ecosystem on average annually



Source: Technopolis Group and Kapa Research, 2023

---

[50] https://op.europa.eu/en/publication-detail/-/publication/accce9ee-db11-11ec-a95f-01aa75ed71a1
[51] https://ec.europa.eu/eurostat/cache/metadata/en/isoc_e_esms.htm
[52] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-industrial-strategy_en
[53]https://clustercollaboration.eu/sites/default/files/WYSIWYG_uploads/eu_mobility_transport_automotive_ecosystem_29092020f_003_0.pdf

Adoption of green technologies for resource efficiency

One of the most important aspects for the success of the green transformation from a demand-side perspective is the adoption of green technologies and measures to increase resource efficiency. To monitor the status quo of the uptake of these technologies and measures, detailed information on the implementation of specific resource efficiency technologies and measures where collected.

In this respect, the detailed survey results show that **SMEs in the mobility, transport, and automotive ecosystem are most concerned about their energy use**, as about **20% indicate having adopted energy-saving technologies over the past 5 years** (which is the highest implementation rate of any of the resource efficiency technologies included in the survey).

Methods related to the recycling of materials and technologies for recycling form the **second most frequently implemented technology cluster** (both with adoption rates of approximately 19% of the surveyed SMEs). The third most frequently implemented type of resource efficiency technologies, where technologies related to renewable energies, as approx. **16% of the SMEs confirmed to have invested in the use of renewable energy solutions within the past 5 years**.

On the other side of the spectrum, regarding the least frequently implemented green technologies and measures, the survey reveals that technologies belonging to the field **hydrogen technologies and biotechnology had so far only been taken up by approx. 6%, respectively 9%, of the surveyed SMEs, indicating a lower demand for these families of technological solutions**.

Furthermore, the survey also inquired into plans for green technology adaptation in the near future (adoption within the next two years). The results show that amongst green technology laggards (i.e. the share of respondents that have not yet adopted any of the surveyed green technologies and measures), only a few companies have concrete plans to implement resource efficiency technologies in the upcoming years (well below 5% for each technology).

Figure 10: Adoption of green technologies within the mobility, transport and. automotive industrial ecosystem

	Answer	
Technology	Already using	Planning to adopt
Energy-saving technologies	20,1%	2,9%
Recycled materials	19,0%	1,9%
Recycling technologies	18,9%	1,6%
Renewable energy	15,9%	4,0%
Clean production technologies	13,4%	3,2%
Carbon capture technologies	11,8%	2,8%
Bio-based materials	11,4%	2,3%
Additive manufacturing	11,4%	2,9%
Biotechnology	8,8%	1,6%
Hydrogen	6,1%	2,0%

Source: Technopolis Group and Kapa Research, 2023

The technology adoption rates identified in this study are complemented by the analyses in the Flash Eurobarometer 498, which are based on data collected in the fall of 2021 (the fieldwork for this study was conducted spring 2023). The Eurobarometer results confirm that SMEs in the mobility sector have most frequently been concerned with, and engaged in, the adoption of technologies to minimise waste (58% uptake), saving energy (57%), materials (52%), and water (44%), as well as circular and recycling strategies (42%). While the Eurobarometer results confirms the general importance of energy-saving and material recycling within the resource efficiency technologies, they also show a significantly larger magnitude in the technology adoption rates.

The lower absolute magnitude of technology adoption for any single technology found in the more recently conducted EMI survey is striking, as they may imply a significant reduction in the uptake across the entire spectrum of surveyed green technologies. On the other hand, however, the EMI survey respondents simultaneously reported increases in their general investments in the green transition in recent years. Accordingly, these **complementary studies paint a somewhat ambiguous picture**, as **no clear trend appears to have emerged in respect to an increasing or decreasing uptake of the green transition in recent years**, at least on the level of individual technologies.

Further investigations into the uptake of green technologies are hence needed, to investigate whether there is a persistent trend towards a lower uptake of green technologies, or whether the increased investments of recent years will manifest in higher technology adoption rates in future versions of the EMI survey as well. Furthermore, it appears that **factors other than a perceived lack of relevance, lack of strategic focus, or missing investment capabilities of the SMEs**, need to be considered, when trying to identify the factors **hindering a more widespread uptake of green technologies**.

Energy saving technologies and the usage of renewable energy sources

According to a recent study based on data from the European Environmental Agency Database[54] and Eurostat[55] from 2018, by Tsemekidi-Tzeiranaki et al (2023)[56], was the EU's **transportation sector (a sub-sector of the mobility ecosystem) by itself responsible for about 34% of the EU's total energy consumption**. The sheer magnitude of energy consumed in this sector alone hence exemplifies the unique economic importance of energy efficiency and energy saving technologies for the firms active in the mobility ecosystem, as well as for reaching the EUs ambitious zero carbon emission goals.

In the current version of the EMI survey, however, only **about 20% of the survey respondents indicated to have invested in energy saving technologies in recent years,** leaving the large majority of **80% of the SMEs in the ecosystem with an unexplored potential for the optimisation of their energy consumption patterns**. Taking into account recent geopolitical events, macroeconomic trends, and environmental crises, however, it appears to be plausible that **energy saving technologies will rise in their importance in future years**, making further **increases in the adoption rates of energy saving technologies appear highly likely** in future versions of this survey.

Renewable energy sources

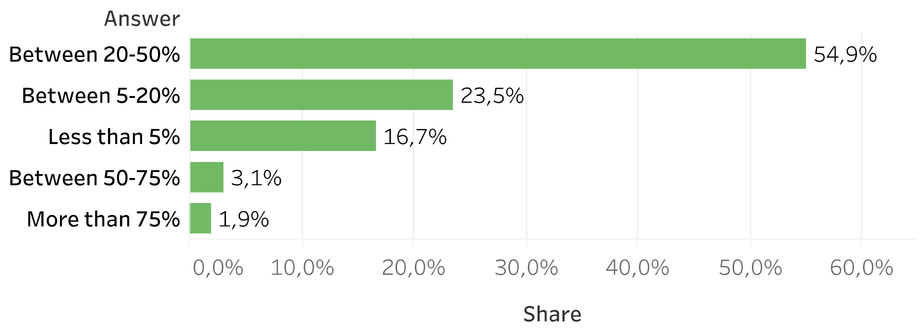
In addition to the much needed reduction in the overall energy usage, via energy saving technologies, also the uptake of renewable energy sources plays an important role in the EU's zero emission strategy and is hence likely to be closely linked to future developments in the mobility ecosystem.

While to date, **only about 16% of the SMEs in the mobility ecosystem already rely on renewable energy technologies,** a deeper analysis of the renewable energy usage of the surveyed SMEs reveals that **more than half of these firms (approx. 55%), has**

[54] https://www.eea.europa.eu/data-and-maps (last accessed: November 2020).
[55] https://ec.europa.eu/eurostat (last accessed: September 2020).
[56] https://doi.org/10.1016/j.tra.2023.103623

managed to substitute between 20% and 50% of their total energy consumption by renewable energy sources.

Figure 11: Share of renewable energy use within total energy consumption



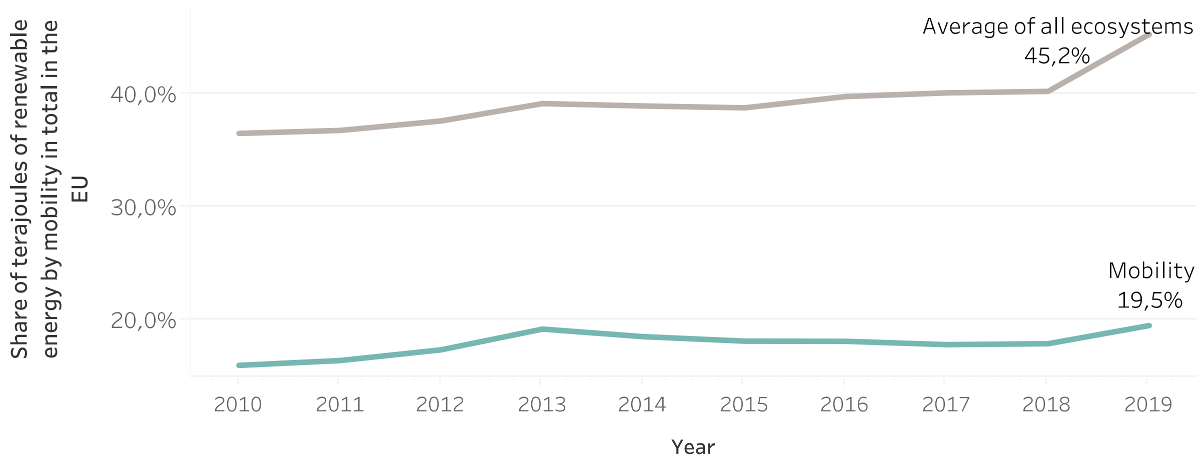
Source: Technopolis Group and Kapa Research, 2023

These results indicate a remarkable latent potential for the usage of renewable energies in the mobility ecosystem. However, substitution shares above 50%, are achieved only by a small fraction of the surveyed companies. Namely, only a combined 5% of the SMEs that already employ renewable energy sources has managed to exceed the 50% renewable energy threshold. These findings indicate that a complete substitutability of non-renewable energy sources appears to be highly unlikely in the near future.

As an extension to the EMI survey data, and to provide a comparison to other industrial ecosystems, the renewable energy share of the mobility, transport and automotive industrial ecosystem was also monitored based on statistics provided by Eurostat. Although the last available year of the Eurostat data dates back to before the pandemic, notably 2019, the data allows to trace the evolution of the share of renewable energy consumed by firms in the mobility sector to other industrial ecosystems, over time.

Figure 12 plots the EU27 average use of renewable energy and the mobility ecosystem's renewable energy use over time, showing that, for instance in 2019, **renewable energies accounted, on average, for about 45% of the energy consumption across all industrial ecosystems, while for the entire mobility ecosystem only about 20% of the total energy usage was covered by renewable sources.**

Figure 12: Evolution of the share of terajoules of renewable energy use by the mobility, transport and automotive ecosystem in the total EU27 IEs (2010 – 2019)



Source: Technopolis Group, 2022, based on Eurostat [ENV_AC_PEFASU]

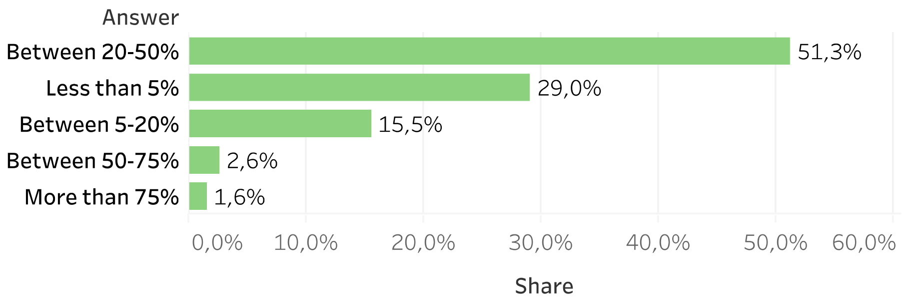
Recycling, circular and sustainable sourcing

Further analysis into the second most frequently adopted type of resource efficiency technologies, i.e. use of recycled materials and the adoption of recycling technologies (see figure 12), shows the significant latent potential of recycled materials and recycling technologies to be incorporated into the value creation processes of the mobility ecosystem stakeholders.

More than half of the mobility SMEs, that already employ recycled materials or recycling technologies in their value creation processes, reported to be able to substitute between 20-50% of their new material use by recycled materials.

However, also in this case only a small number of SMEs can exploit the full potential of the recycling technologies. Only a minor 4% of the SMEs, that reported to have already incorporated recycled materials into their workflows, indicated be able to substitute more than 50% of their new material use by recycled materials (see Figure 13).

Figure 13: Share of recycled materials used within production among those that have adopted recycling



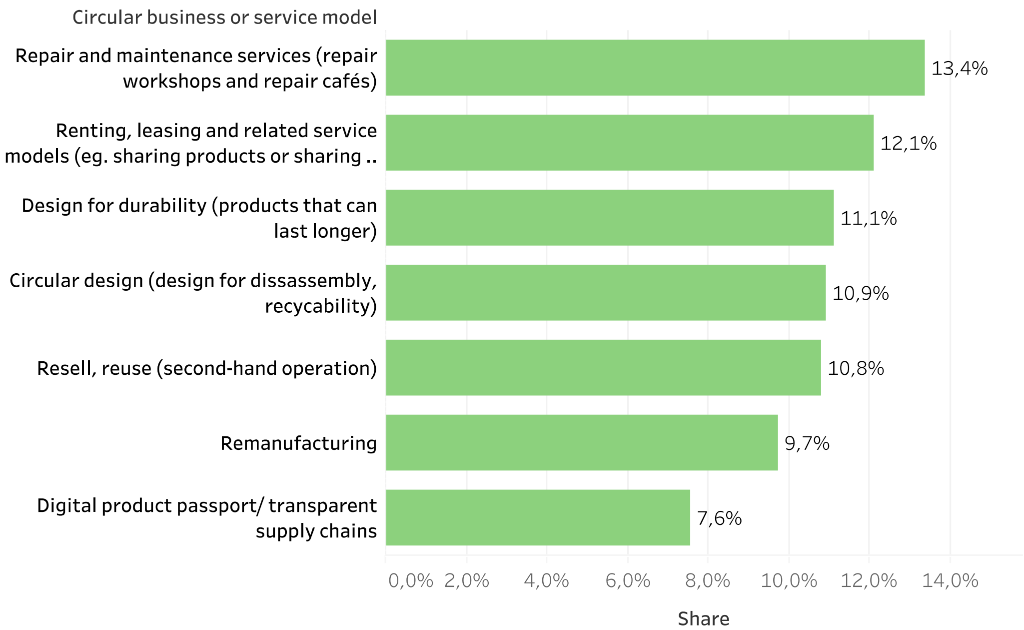
Source: Technopolis Group and Kapa Research, 2023

Adoption of green business models

Beyond the adoption of green technologies, sustainable business models are needed to ensure the economic sustainability of the green transformation. Accordingly, the EMI survey also inquired into the **adoption of circular business models and other non-technical, service-based mobility and transport solutions, among the SMEs of the mobility ecosystem**.

The survey results show no clear trend towards any single type of sustainable business model among the SMEs in the mobility ecosystem. Combined, however, sustainable business models make up for a sizable fraction of the entire business model landscape of SMEs within the mobility ecosystem, as **approximately 78% of the surveyed SMEs have at least partially adopted one or another type of the green business models assessed in the survey** (see Figure 14). This remarkable and encouraging finding, however, is at least in parts potentially also driven by the characteristics of the surveyed population of SMEs (especially micro-enterprises and small enterprises) and their positioning within their respective value chains.

Figure 14: Adoption of green business models and non-technological solutions within mobility ecosystem



Source: Technopolis Group and Kapa Research, 2023

The detailed survey results furthermore indicate that the largest share of sustainable business models implemented by the respondents' companies, approximately 13%, belong to the cluster of repair and maintenance service models. This result is most likely driven by the share of micro-enterprises (<10 employees) and small enterprises (10-50 employees) in the sample and their traditional business models, as these are more likely to be located in the later stages of the respective product life cycles and mobility service value chains.

Mobility as a Service (MaaS) solutions, such as renting, leasing, and related service models, were reported to be the second most frequently employed cluster of sustainable business models in the mobility ecosystem. About 12% of the respondents reported to have implemented such a business model that contributes to the sustainable case by reducing ownership rates in favour of a more sustainable mobility-sharing paradigm. These business models include traditional approaches, such as on demand taxi and fright services, long and short-term vehicle and transportation rental models, but also more novel, digitally enabled mobility on demand and sharing economy services.

The remaining circular and resource efficient business models assessed in this study, such as those designed to build more durable products, those that incorporate circular principles already in the product design, business models based on re-selling or reusing second hand products, as well as remanufacturing business models, were each incorporated by approximately 10% of the surveyed SMEs.

Lastly, a question regarding the usage of digital product passports, and related business models, was included in the survey, as these form one of the key enabling technologies, for the development of circular solutions and transparent supply chains, highlighted in the sustainable products initiative[57] of the European Commission. However, to-date, digital product passports and related business models were indicated to be used by only 2.3% of the survey respondents, indicating a low uptake of the technology, and related business models, despite some of the interviewees indicating a high interest in this topic for their future work.

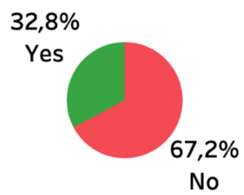
[57] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12567-Sustainable-products-initiative_en

Adoption of environmental standards

The third dimension of the green transformation, that was assessed in the EMI survey, relates to the adoption of environmental standards and norms via third party certifications. These certifications can act as an important step-stone, or catalyst, for establishing truly sustainable business practices within an enterprise seeking to obtain such a certification, but also signal a firms' commitment to sustainability to external stakeholders and partners.

Accordingly, the survey inquired into whether the respondents' companies had already obtained any type of certification on any type of environmental standards in recent years. **32.8% of the respondents indicated that they had already obtained such a third-party verified environmental certification in the past** (see Figure 15).

Figure 15: Share of respondents indicating that they have obtained a third-party verified environmental certificate



Source: Technopolis Group and Kapa Research, 2023

There are a number of certificates and standards that aim to reduce energy consumption, improve energy efficiency, and promote sustainable energy practices. For this study, **the number of issued ISO 14001 certifications was chosen as a representative indicator for the uptake of certifications on environmental standards**.

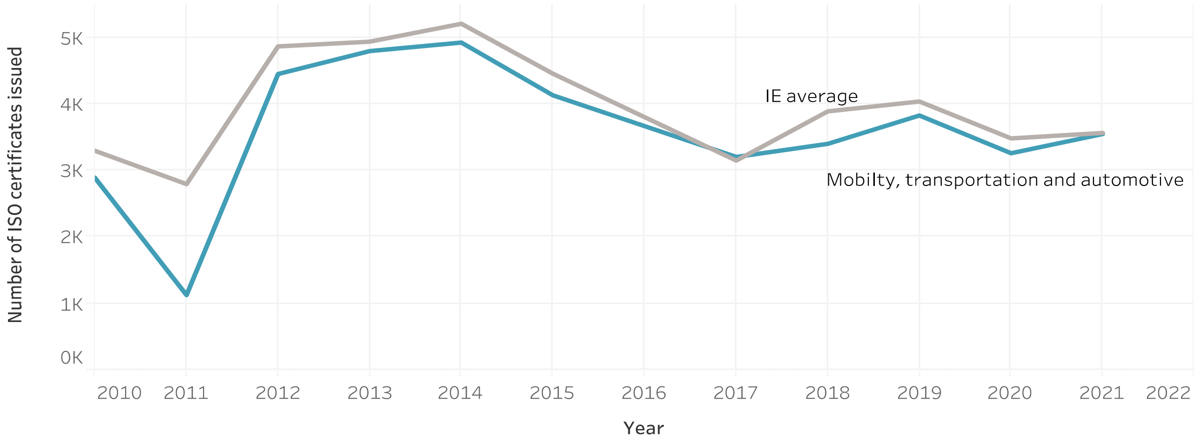
ISO 14001 includes a set of standards that any company can follow to implement an effective environmental management system. By adopting the practices suggested by the norm, firms can substantially reduce their environmental footprint. The number of environmental certificates issued in a specific ecosystem over a certain time period then indicates the ecosystem's progress towards the application of environmentally friendly business practices and production methods. For the purposes of this report, ISO data were accessed via the ISO survey of certifications to management system standards[58].

As a complement to the survey results, Figure 16 shows a time series plot of the number of ISO certifications issued to firms within the mobility ecosystem against the average of issued certification of all other industrial ecosystems from 2010 to 2022. For both time series, the plot shows at best a stagnation in the uptake of environmental standards over the entire time period, and a continuously decreasing trend in issued certifications in recent years, as **since reaching a peak in 2014, the annual number of ISO 14001 certifications issued to companies of the mobility ecosystem appears to have steadily decreased.** (Specifically, the annual ISO survey indicates that in 2014 about 5 000 certificates where issued to companies in the mobility ecosystem within the EU27, however, this number decreased to 3 500 certificates in the year 2021.)

As both time series closely mimic each other, there appears to be a more universal trend towards a lower uptake of environmental certificates, rather than a mobility ecosystem specific development.

[58] ISO (2022) ISO Survey of certifications to management system standards. Accessed on https://isotc.iso.org/livelink/livelink?func=ll&objId=18808772&objAction=browse&sort=name&viewType=1

Figure 16: Number of environmental certificates issued



Source: Technopolis Group, 2022, based on ISO

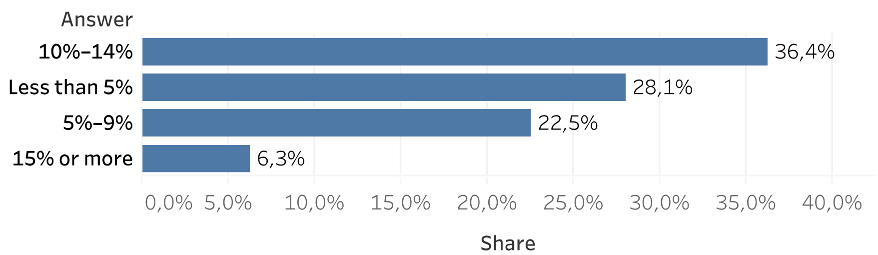
Potential factors that have contributed to this decline in the number of issued certifications are manifold. A particularly plausible explanation, however, pertains to increased efforts required for the certification process and stricter requirements for obtaining the certifications in recent years, as in 2015 the norm had been revised (ISO 14001:2015), and a stronger emphasis was placed on the integration of additional management practices and a life cycle perspective. This addendum to the norm in 2015 coincides with the drop in issued certificates after the 2014 peak had been reached.

3.2. Digital transition of SMEs in the mobility ecosystem

To assess the current state and strategic importance of the digital transformation for the SMEs within the mobility sector, the survey participants were asked whether they had increased their investments in the digital technologies and related business models in recent years. **Close to half of the surveyed SMEs in the mobility, transport and automotive industrial ecosystem** indicated to have **increased their investments dedicated to the digital transformation during the past five years**.

Further enquiry into the specific funds dedicated to the advancement of digital transformation (i.e., the average annual percentage of revenue that SMEs had invested for the adoption of digital technologies and related business models) revealed that **36% of the respondents invested between 10-14% of their revenue in digital technologies**.

Figure 17: Share of revenue/income invested in digital transformation on average annually



Source: Technopolis Group and Kapa Research, 2023

The level of adoption of specific digital technologies relevant for the ecosystem is presented in Figure 18. Overall, **online platforms and cloud technologies were indicated as the most relevant of the digital technologies**, for the surveyed SMEs, **followed by IT software and big data.** Yet, just as for the case of the green technologies, the analysis of the digital technology uptake reveals **rather low adoption rates for any single type of the assessed technologies.**

The use of online platforms by 23.1% of the SMEs in the ecosystem reflects an ongoing dynamic diffusion of the platform economy and a gradual shift towards software-powered transportation platforms within the mobility ecosystem. Digital services provided via online platforms are becoming more and more important as indicated by the survey respondents. This trend is linked to both new smart mobility systems and to the sharing economy, and hence presents a close link to the green transformation, exemplifying the synergies between these two dimensions of the current twin transformation of the mobility ecosystem.

Cloud technologies, defined as the **use of cloud-based software and related cloud platform services, were adopted by 19.7%** of the respondents in the EMI survey. Complementary data by Eurostat[59] provides a more granular picture of the adoption of cloud technologies across sub-sectors of the mobility ecosystem, and reveals that 20.7% of the companies in the "manufacturing of motor vehicles sector" and 16.5% in the "transportation and storage" sectors invested in cloud-computing services, such as CRM software and accounting software, in 2020. When looking at cloud technologies in a broader term, the Eurostat statistics show that 46% of companies in the "manufacturing of motor vehicles sector" and 35.2% in the "transportation and storage" sectors adopted this technology in 2021.

Furthermore, **the EMI survey finds that big data and related data analytics methods have been adopted by 11.3% of the SMEs** in the ecosystem. Eurostat[60] data again provide supplementary insights into the "manufacturing motor vehicles" and "transportation and storage" sub-sectors, as well as the specific application areas of big data methods. Hence, according to Eurostat data for the year 2020, 13.7% of the companies in the "manufacturing motor vehicles" sector indicated to have implemented big data methods to analyse data from internal and external sources, while this share was larger in "transportation and storage", with 21%.

[59] https://ec.europa.eu/eurostat/databrowser/view/ISOC_CICCE_USEN2__custom_6733560/default/table?lang=en
[60] https://ec.europa.eu/eurostat/databrowser/product/view/ISOC_EB_BDN2

Figure 18: Adoption of digital technologies within the mobility ecosystem

	Answer	
Technology	Already using	Planning to adopt
Online platform	23,1%	1,6%
Cloud technologies	19,7%	2,4%
IT software	18,1%	2,9%
Big data	11,3%	2,0%
Artificial Intelligence	10,5%	2,5%
Internet of Things	10,2%	2,0%
Augmented and virtual real..	10,1%	2,1%
Digital micro-factory	9,6%	2,7%
Digital twin	9,5%	1,9%
Robotics	8,1%	3,0%
Edge computing	6,9%	2,3%
Blockchain	3,5%	2,7%

Source: Technopolis Group and Kapa Research, 2023

On the other side of the spectrum of digital technology usage, i.e. **the least frequently adopted digital technologies**, lie technologies such as **digital twins** (including digital micro-factories), **robotics, edge computing, and the blockchain**. These technologies are likely to be the least frequently employed by the SMEs of the ecosystem, partially due to the heavy upfront investments and advanced digital capabilities required for their successful deployment.

Digital twins, for example, are employed to create a virtual replica of a physical product, process, or system, and allow for real time analysis, which provides the basis for productivity increases. The EMI survey, however, finds that only **9.5% of the respondents adopted a type of digital twin technology**. Furthermore, potentially stark differences in the usage of this technology among mobility sub-sectors have to be kept in mind.

Edge computing has been adopted by 6.9% of the SMEs as found by the EMI survey. Edge computing allows the optimisation of data processes and is expected to play a key role especially speeding up processes in connected cars and related mobility services.

Lastly, the number of mobility SMEs that already employ blockchain-based applications is negligible, **as only 3.5% of the respondents indicated to employ blockchain technologies**.

For a deeper analysis into the patterns of digital technology adoption within the ecosystem, **four digital spotlight technologies were selected**, namely **Artificial Intelligence (AI), Internet of Things (IoT), Augmented and Virtual Reality (AVR), and robotics**. For each of these technologies, additional questions were implemented in the EMI survey design, with the goal of assessing specific technology use cases across the mobility ecosystem's value chains and product life cycles. This **analysis revealed heterogeneous uses cases of these spotlight technologies, across different parts of the mobility value chain**[61]**.**

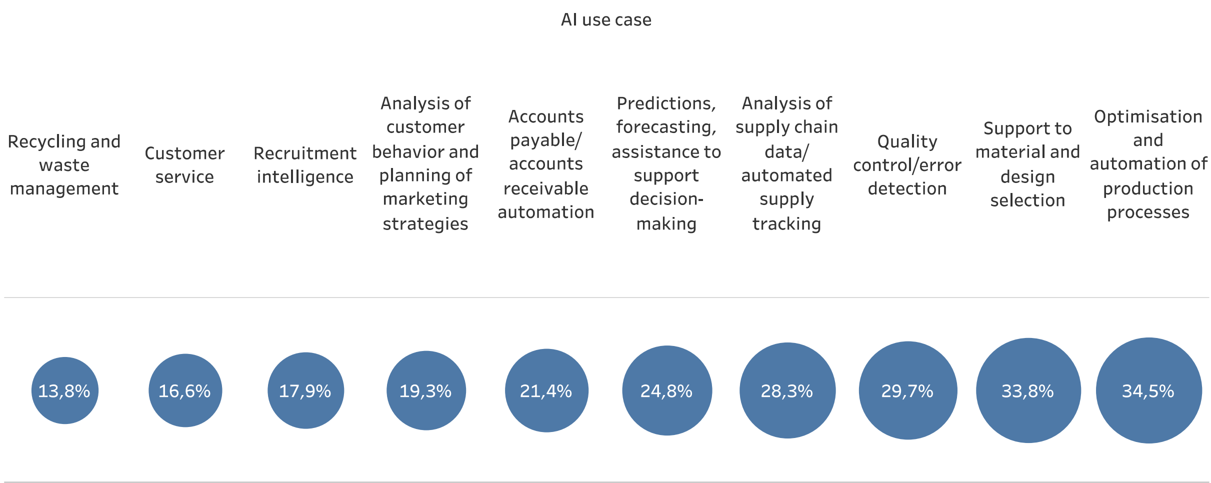
[61] https://www.isc.hbs.edu/strategy/business-strategy/Pages/the-value-chain.aspx

Artificial Intelligence

The Artificial Intelligence uptake of 10.5% among the SMEs of the mobility ecosystem shows a general relevance and applicability of AI in the ecosystem. However, the technology is still far from being widespread. The related indicator in Eurostat[62] corroborates these findings and finds an AI uptake of 11.6% within all enterprises active in manufacturing of motor vehicles. Furthermore, with a slightly lower uptake of 5.3%, have enterprises in the "transportation and storage" sectors adopted at least one type of AI technologies in 2021.

A closer look into the specific use cases for AI technologies reveals the potential of AI technologies to be employed along the entire mobility value chain, across both primary and support activities, as well as a minor share of sustainability centred-use cases (see Figure 19).

Figure 19: Use cases of AI among SMEs in the mobility ecosystem



Source: Technopolis Group and Kapa Research, 2023

The most frequent use cases, however, lie within the primary value chain activities, such as the production processes, notably for **process optimisation and automation (approx. 34%)** and **quality control (~30%)**. Furthermore, supply chain and logistics-related activities, such as the "analysis of supply chain data and automated supply tracking" (~28%) were also among the most frequently named use cases for AI.

Among the support activities where AI had been employed, was the most frequent use case in located in supporting R&D related activities, such as in "the support of material and design selection" (~34%), but also the support of general decision making across the entire value chain, finance processes, customer analysis and marketing, but also minor applications to recruiting intelligence (see Figure 19 for further details).

Notably missing from the top ranks of AI usage are explicitly sustainable use cases, with the exception of recycling and waste management, which had been employed by a minority share of ~14% of the AI adopters.

The diversity of AI use cases, reported above, shows the general applicability of this technology across the different value chain activities of the SMEs within the mobility ecosystem. However, the realisation of the manifold potentials of this **digital technology to also enable sustainable use cases**, hence fostering also the green transition, appears to be **limited in practice so far**.

[62] Enterprises using AI technologies by economic activity, EU, 2021

Internet of Things

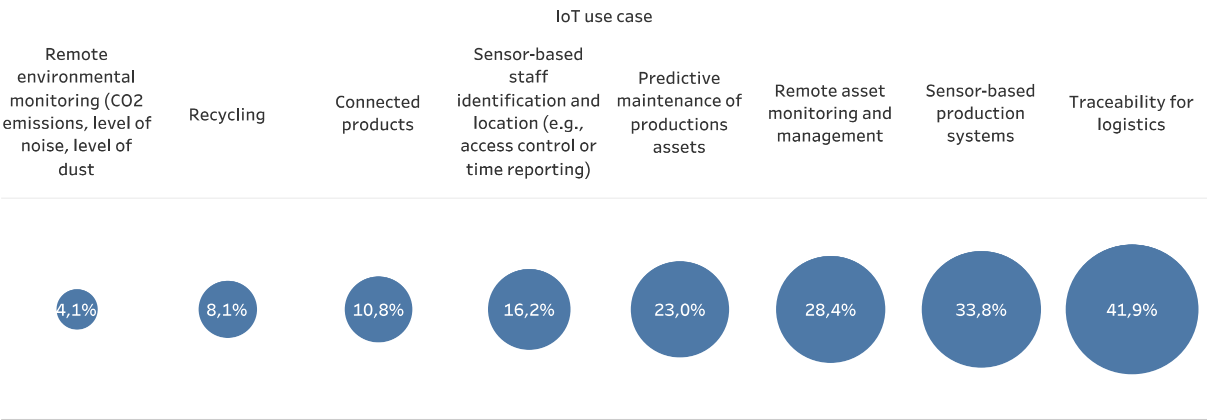
An adoption rate of 10% for the Internet of Things technologies shows that also this **technology** is still **far from becoming mainstream among the SMEs of the mobility ecosystem**. Expertise in this area is not yet necessarily a core competence of traditional automotive manufacturers. This represents, on the one hand a huge potential for technology and IT companies, which are investing in the development of technology solutions and complementary mobility services, but, on the other hand, a challenge for European automotive companies to achieve and maintain competitiveness in the future.

However, there is high potential to this technology for the ecosystem actors, due to the vast amounts of data that is generated along the various value chains of the ecosystem. Accordingly, the uptakes of different IoT use cases was further assessed in the EMI survey.

Survey respondents indicated the **most frequent use of IoT technologies in primary value chain activities**, more specifically, activities related to operations/production processes, as well as value chain and logistics-related activities. In particular, the most frequent uses cases were found in enabling "traceability for the logistics" (~42%), such as automatically tracking materials and products, and using IoT for inventory and warehousing. Furthermore, the use of "sensor-based production systems" has been highlighted as a frequent IoT use case by about 34% of the respondents, as well as remote asset monitoring and management (28%). (For further use cases see Figure 21).

Sustainability-focused uses cases of IoT are again **among the rarest** of the specific technology use cases, as IoT has been indicated to be used to support recycling activities by only 8.1% of the technology adopters, and remote environmental monitoring only by 4.1%. Accordingly, also for the case of IoT technologies, appears the realisation of the latent potential for **synergies between the green and digital transition** to be **an exception**.

Figure 20: Use cases of Internet of Things



Source: Technopolis Group and Kapa Research, 2023

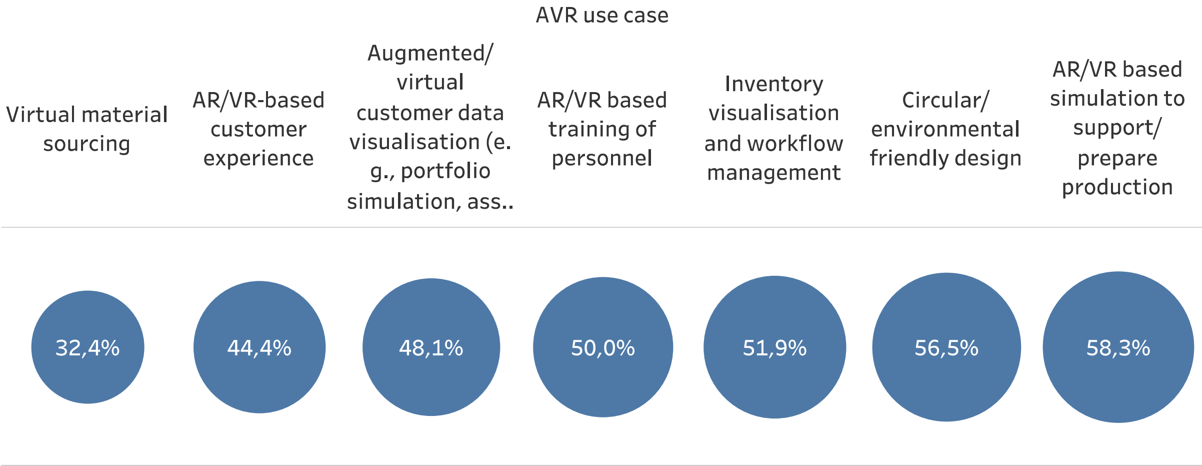
Augmented and Virtual Reality

Augmented and virtual reality (AVR) technologies have been implemented by about 10% of the surveyed SMEs. AVR is used **most frequently in primary value chain activities**, such as for supporting the production process and its preparatory steps, by simulating products, or their assembly and manufacturing steps (~58%). For the visualisation of inventories and workflow management (~52%), or even virtual personnel trainings (50%).

In respect to support activities, have AVR technologies been frequently employed for the purpose of customer data visualisations (~48%), to create more immersive opportunities for virtual customer experiences (~44%), or even virtual material sourcing (~32%).

For AVR technologies, have **circular or environmentally friendly design use cases been mentioned among the most important use cases** (see figure 22, below, for the complete overview of use cases for AVR applications).

Figure 21: Use cases of augmented and virtual reality among SMEs in the mobility ecosystem



Source: Technopolis Group and Kapa Research, 2023

Robotics technologies

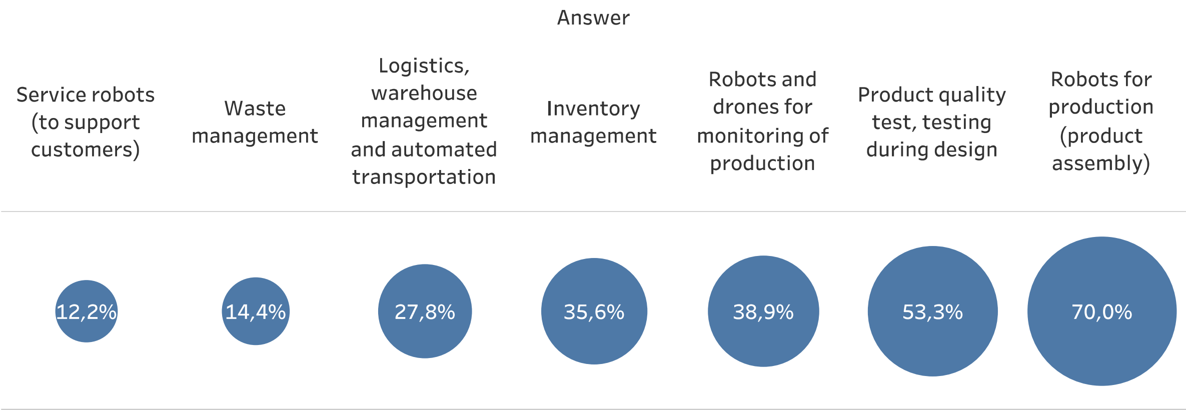
As the last of our spotlight technologies, were the specific use cases for robotics technologies assessed in the underlying version of the EMI survey. Among the SME of the ecosystem, **8% of the respondents expressed the employ robotics solutions in their production processes**. Supplementary data by Eurostat[63] indicates that 36.1% of the enterprises in "manufacturing of motor vehicles" and 2.6% of companies in "transportation and storage" used industrial or service robots in 2022, exemplifying the importance of robotics technology for the automotive sector specifically.

The most important use case of robotics is accordingly also found among the primary value chain activities, namely in production and product assembly (70%), as it is also found in the ICT usage survey on the use of robotics. Further important use cases for robotics were indicated to lie in activities related to product quality testing and inspection processes (~53%), monitoring production via the use of robots and drones (~38%), or inventory management (~36%) or the automation of transportation and logistics processes, and warehouse management (~28%).

Robotics use cases with a specific focus on sustainability have not been mentioned by the survey participants. Again, **leaving** possible synergies **between** this last type of **digital spotlight technologies and the green transition mostly unrealised**.

[63] https://ec.europa.eu/eurostat/databrowser/view/ISOC_EB_P3DN2__custom_6730619/default/table?lang=en

Figure 22: Use cases of robotics among SMEs in the mobility ecosystem



Source: Technopolis Group and Kapa Research, 2023

3.3. The role of collaborative actions to foster the uptake of the twin transition

Collaborative actions, such as public-private initiatives and partnerships, can play a significant role for increasing the uptake and diffusion of green and digital technologies across an industrial ecosystem. Such partnerships have already emerged within the mobility ecosystem and successfully contributed to the twin transition across the European Union Member States. The nature and quality of these initiatives, as catalysts of the green and digital transition, however, can best be understood by the means of specific, richly detailed examples. Accordingly, to convey the importance of the contributions of these change agents, two qualitative case studies on different types of public-private initiatives have been conducted for this report, by means of desktop research.

Firstly, a single case study was conducted on the role of open data ecosystems for advancing the diffusion of both green and digital transitions among a variety of stakeholders, using the example Catena-X and the overarching principles and standards set by the Gaia-X framework. Secondly, a set of multiple smaller case studies has been conducted, to exemplify the importance of public-private technology centres for supporting the development and diffusion of green and digital technologies all across Europe.

The role of open data ecosystems in fostering the green and digital transition of the mobility ecosystem

Data and particularly data-driven innovation are becoming increasingly important in the automotive industry as companies seek to stay competitive, achieve growth, and promote sustainability. For example, through the exchange of data encompassing product and material origins, composition, and movement, collected previously via advanced digital technologies such as contactless identification and real-time tracking (RFID), valuable insights can be gained. These insights allow companies to identify opportunities for reducing their environmental impact, thereby distinguishing suppliers who embrace sustainable practices, as well as to effectively respond to and recover from disruptions and disturbances within their supply chains. Additionally, harnessing the power of data through cloud computing, the Internet of Things (IoT), big data analytics, and artificial intelligence (AI), automotive companies can gain a significant competitive advantage while unlocking new avenues for innovation and expansion.

Despite this significant potential, the current data landscape in the automotive value chain is highly complex, fragmented, and lacks transparency, interoperability, and security. One example of this issue is the lack of transparency and standardisation in the supply chain data. As companies strive to become more sustainable and reduce their environmental footprint, they are increasingly looking to their supply chains to identify opportunities for improvement. However, as they are often complex, for instance due to global character, it can be difficult to track and measure environmental impacts. Without transparency and standardised data, it is challenging to assess the environmental performance of each supplier accurately. To address this issue, there is a need for innovative and secure solutions in the automotive data landscape to enable more efficient and secure sharing of data across the value chain while protecting the privacy of each company.

To address this issue, the European Union has launched a strategic initiative known as GAIA-X[64], which aims to create a secure, sovereign, and interoperable data infrastructure for Europe. The main trigger for the initiative was the concern about data sovereignty, security, and the increasing dominance of US and Chinese cloud providers in the European market. GAIA-X seeks to establish a European alternative to these dominant providers by creating a trusted, open, and transparent data infrastructure that is accessible to all European companies and institutions. The goals of GAIA-X include creating a federated data infrastructure, ensuring data **sovereignty**, promoting **interoperability** among different cloud providers and data services, and fostering **innovation** by promoting collaboration and co-creation among stakeholders. First, by establishing a European data infrastructure, GAIA-X ensures that data remains under the control of European companies and institutions, and that European values and interests are protected. Second, GAIA-X aims to solve the issue of the current data landscape, which is fragmented and complex characterised by different services operating in silos. Finally, GAIA-X fosters innovation by providing access to data and services facilitating collaboration and co-creation among stakeholders.

GAIA-X offers a comprehensive industry perspective that goes beyond the boundaries of individual sectors, enabling influential industries to establish secure, trustworthy, and interoperable data ecosystems. Building on this ground-breaking initiative, has the German automotive industry, supported by stakeholders from the public sector, launched a bold project called Catena-X, which aligns with the overarching principles of GAIA-X but is focused specifically on the automotive value chain[65]. The primary objective of Catena-X is to create a "universal language" for data in the entire automotive industry and implement a standardised data architecture that facilitates seamless data exchange and collaboration among all stakeholders. Furthermore, the project aims to safeguard data sovereignty by establishing a governance framework that empowers companies and institutions across the automotive value chain to retain ownership and control over their data.

Put differently, Catena-X empowers the automotive industry, a significant catalyst in the mobility ecosystem, to leverage the supranational GAIA-X ecosystem and its standards. This collaboration enables the automotive industry to effectively embrace a data-driven transition, driving innovation and progress within the sector. In addition, it helps to promote interoperability and collaboration among different industry-sectors, facilitating data sharing and exchanging across domains, not only within, but also beyond the mobility ecosystem. Finally, it contributes to the overall goal of creating a resilient and sustainable digital future for European automotive industry.

The case of Catena-X: An open data ecosystem for fostering the twin transition of the mobility sector

One of the significant challenges in the complex automotive value chain is the limited visibility that each participant has beyond their immediate network partners or contractors, and the specific parts they provide. Complex interconnections among subsystems and components make it nearly impossible to obtain a comprehensive overview of the entire supply chain without robust data ecosystems. This becomes particularly relevant in today's volatile supply chain environment where, for instance, disruptions caused by a single supplier's inability to deliver as planned can cause significant damage of the entire supply chain. This is where the Catena-X data ecosystem comes into play. As a "general" system

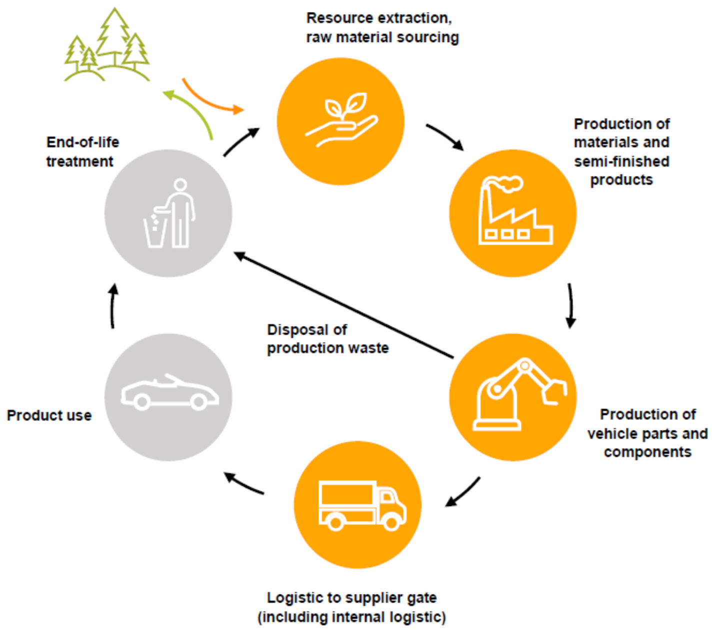
[64] https://gaia-x.eu
[65] https://catena-x.net

designed to manage and share data within the automotive supply chain network, Catena-X has the potential to enhance transparency by providing a comprehensive view of the entire ecosystem detecting and mitigating thereby supply chain disruptions at an early stage. By having access to real-time data and insights collected using technologies like for example RFID, stakeholders can anticipate potential disruptions, react promptly to unexpected events, and implement appropriate contingency plans. Ultimately, this proactive approach helps minimise the negative consequences of supply chain disruptions and ensures the smooth functioning of the overall ecosystem. Moreover, Catena-X facilitates the sharing of data related to real CO_2 emissions, which is crucial for minimising the carbon footprint of the entire automotive sector. By providing all participants with standardised data on the origin, composition, and transportation of products and materials, the platform empowers all companies in the mobility ecosystem to make better-informed decisions and adopt more sustainable practices.

Catena-X functions by harnessing open standards and providing a wide range of services that cover data storage, processing, and analytics. This creates an institutionalised data ecosystem where all participants are interconnected digitally, forming seamless value chains. It ensures equitable participation and empowers each partner to retain full control over their own data. Rather than prioritising data monetisation, Catena-X's main objective is to leverage data to establish novel value chains and enhance current processes, thereby fostering collaborative value generation through practical applications[66]. It plays, hence, a vital role in providing a "trust anchor" that enables free market access for all participants[67].

There are currently 10 industry-relevant use cases, which have been developed and tested in a user-oriented manner[68]. Two of them are particularly relevant for the twin transition: sustainability and circular economy.

Figure 23 Documenting and exchanging real carbon data along the value chain



Source: https://catena-x.net/en/benefits/sustainability

Catena-X facilitates the establishment of a transparent and traceable digital representation of a company's supply chain in real-time, thereby assisting businesses in tackling

[66] Bitkom (2021). Catena-X: Eine Dateninfrastruktur für die automobile Wertschöpfungskette. Vortrag im Rahmen der Digital Mobility Conference am 24. November 2021, mit Oliver Ganser, Programmleitung Catena-X, BMW. URL: https://www.youtube.com/watch?v=Df4-qpLfw8E (letzter Abruf am 20.3.23).

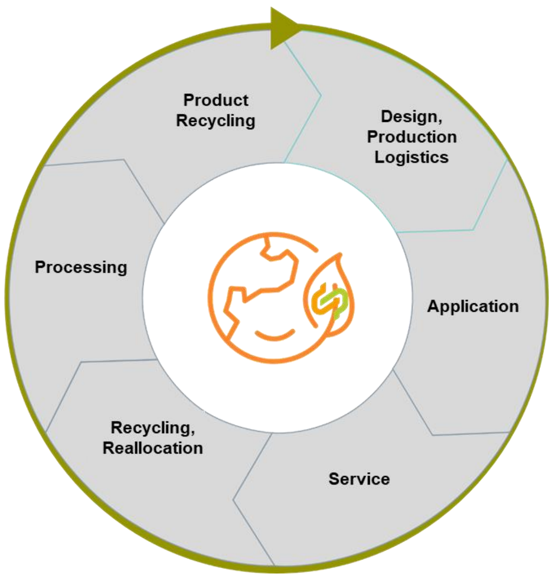
[67] SAP (2022). CATENA-X: Industry Network & Technology for a Data Driven Value Chain

[68] https://catena-x.net/en/benefits

sustainability challenges (see Figure 23). By sharing data on the origin, composition, and movement of products and materials, companies can identify areas for reducing their environmental footprint. This information can help companies identify suppliers who engage in sustainable practices and avoid those who engage in practices that harm the environment. By choosing sustainable suppliers, companies can ensure that their products are produced in an environmentally responsible manner.

In addition to tracking the origin of raw materials, Catena-X can also enable companies to monitor the energy consumption and carbon emissions associated with the production and transportation of products. By so doing, companies can identify areas where they can reduce their environmental impact, such as by using more efficient production methods or by using alternative transportation modes. Furthermore, Catena-X can help companies manage waste and recycling by providing them with information on the composition and disposal of materials. This information can help them identify opportunities to reduce waste and increase recycling, leading overall to a more sustainable supply chain. Finally, by enabling companies to share data on sustainability practices across the supply chain, Catena-X can also promote collaboration and innovation. Companies can learn from each other's best practices and work together to develop new approaches to sustainability.

Figure 24 Documenting and exchanging of data on the individual lifecycles along the value chain



Source: https://catena-x.net/en/benefits/circular-economy

Second example in the context of twin transition is **circular economy** organised across industries.[69] Exchanging data about the individual lifecycles with other companies in the network allows for better tracking and tracing of materials, components or products, making it easier to identify opportunities for reuse, recycling and remanufacturing. For example, a company that produces plastic packaging could use Catena-X to share data about the materials used in their products, as well as information about the production process and any certifications or standards they adhere to. Other companies in the network can use this data to identify opportunities for recycling or upcycling the packaging material, or to find ways to reduce waste in the production process. Another example in this context is in the area of product design and development. By sharing data about materials and processes, companies can collaborate to create products that are more easily disassembled and recycled at the end of their life cycle, for instance in the area of battery production. This could involve designing products with modular components that can be easily replaced or upgraded or using materials that are more easily recyclable.

[69] https://catena-x.net/en/benefits/circular-economy

The case of Catena-X: Challenges for establishing an open data ecosystem for the mobility sector

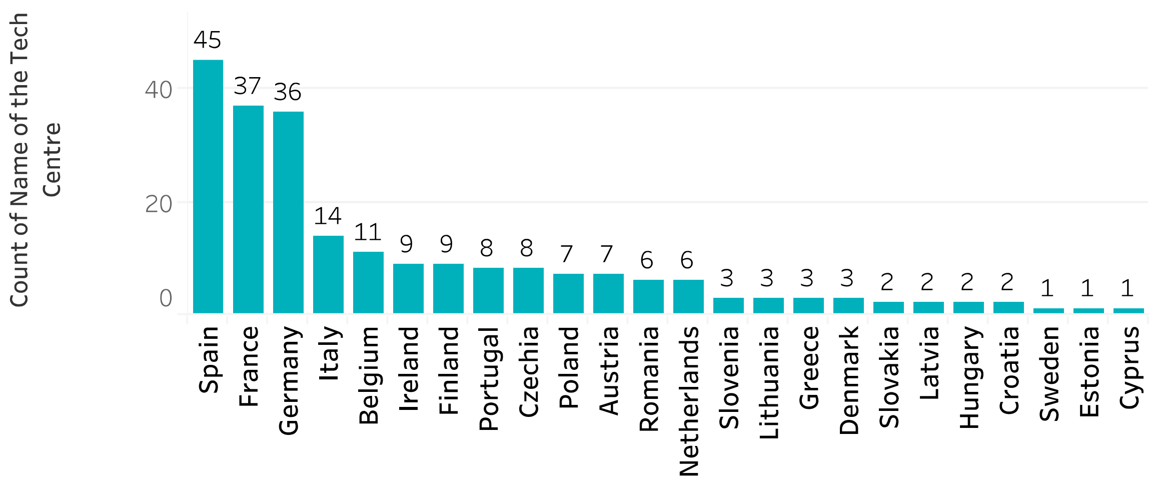
While the various benefits of an open data ecosystem, such as Catena-X, and its applications for the twin transition of the automotive sector, a sub-sector of the mobility ecosystem, have been extensively covered in the previous section, they also face some significant challenges. **One of the primary challenges is to ensure the adoption of the system by various stakeholders**. For instance, since Catena-X is set-up as a decentralised ecosystem, it requires a broad participation of stakeholders to be effective. Therefore, persuading various organisations to join the network and share their data becomes of paramount importance. In this regard, **trustworthiness, or credibility of the system as a whole**, its **legitimacy**, as well as its **relevance for the stakeholders** of the mobility ecosystem **have to be ensured**.

In the case of Catena-X, in order to achieve these goals, various strategies are employed to try ensuring a high adoption of the ecosystem and diffusion across the entire value chain. For instance, **promoting the use of common standards and protocols**[70] aim at ensuring trust and legitimacy among future data ecosystem participants. **Providing support offers and guidance to organisations throughout their implementation journeys**[71] is intended to help ensuring the applicability, feasibility, and relevance of the system with respect to the needs of future stakeholders. Lastly, the **variety of actors that make up the current Catena-X consortium**, as well as the **support provided by public entities**, aims at ensuring the data ecosystem's legitimacy. Accordingly, with these combined measures, Catena-X aims to address the challenge of persuading diverse organisations to join the network and share their data, ultimately creating a thriving decentralised ecosystem that benefits all participants.

3.4. Technology centres supporting technology uptake

Collaboration and resource orchestration are core capabilities required for the transition of any industrial ecosystem, especially when these ecosystems face disruptions of the scale and magnitude that the twin transition presents.

Figure 25: Technology centres per country – mobility



Source: Analysis based on Advanced Technologies for Industry Technology Centre Mapping, 2023

[70] https://catena-x.net/en/catena-x-introduce-implement/standardisierung
[71] https://catena-x.net/en/catena-x-introduce-implement/onboarding

Suitable change agents, knowledge brokers, and connectors, are necessary to provide and facilitate this important ecosystem capability. The technology centres listed in the EC's 'Technology Centre Mapping' system present such a change agents, due to their technical expertise and ability to bring together and steer collaboration among various types of actors in their own ecosystems and beyond. They provide the service of gathering and sharing information about innovators of industrial ecosystems in a structured way, which is a crucial to detect gaps, improve collaboration, foster innovation, and strengthen entire innovation ecosystems.

Figure 25 presents the number of technology centres that are active in the mobility industrial ecosystem per European country and shows that Spain (45) is the country with the highest number of technology centres in Europe, followed by France (37) and Germany (36). The top five is further complemented by Italy (14) and Belgium (9). These countries, however, might host additional technology centres active in the mobility ecosystem, which are currently not registered to the technology centres mapping.

The following examples serve to illustrate the activities and scope of technology centres active in mobility, their links with the broader ecosystem as well as examples of recent activities in which they are involved. They include the following three cases: NAITEC (ES), TEMA –Centre for Mechanical Technology and Automation (PT), and CEA Mobility Platform (FR).

Box 1: Example Technology Centre: NAITEC (ES)

Name of the Centre	**NAITEC (ES)**

Location and scope

In 2017, the Government of Navarra, together with the Public University of Navarra (UPNA), decided to create a new Technology Centre working in the automotive and mechatronics sectors, to promote the priority lines of the regional government's Strategic Plan. Therefore, NAITEC was born in 2018, made up of the staff from the former CEMITEC and of researchers from the UPNA.

The objective of NAITEC is to improve the competitiveness of companies by providing innovative and sustainable solutions in the following areas:

- **Mobility -** NAITEC focuses on two of the main challenges of the sector in the market: to make more efficient and sustainable products and to develop more energy efficient autonomous vehicles.
- **Mechatronics -** NAITEC works in the digital transformation of industrial processes and in the creation of smart mechatronic products.
- **The Business Unit**, through which the Centre promotes entrepreneurship and the creation of innovative technology-based companies.

NAITEC is associated to ADItech, a private non-profit foundation coordinating the R&D network in Navarra and representing NAITEC in the European Factories of the Future Research Association (EFFRA) and in the Sustainable Process Industry through Resource and Energy efficiency (SPIRE). Recently, NAITEC joined the Spanish Centre for Industrial Cybersecurity.

Main services and equipment

NAITEC offers technological services and equipment for various sectors such as mobility, wind power, energy, agrifood, packaging, household appliances, and construction, among others.

It provides the following service packages:

- **Material testing**, including Raw Material Characterisation (RMC), quality inspection (end product checks), failure and defect analysis, surveillance and selection of materials, and product recommendations and improvements.
- Solutions for conducting characterisation and durability tests on components and mechanical systems.

- **Electronic product testing and validation**, offering tests on Electromagnetic Compatibility (EMC), Electrical Safety (ES) and Environmental Tests for the certification of products in the field of industrial and consumer electronics. - **Simulation and modelling services** in fluid mechanics, structural mechanics, thermodynamics, multi-physics, multibody, and numerical methodology. - Entrepreneurship promotion and diversification services. To provide these services, NAITEC has the following infrastructure and equipment: o Electronic product testing and validation laboratory o Electronic development laboratory o Test benches and validation of mechanical components o Materials laboratories o Functional printing plant o Nanotechnology laboratory o NaVEAC Drive-Lab Urban Test Bed[72]
Recent projects related to the green and digital transition in mobility
- **TWIN-ZERO** addresses the technological challenges for the advanced manufacturing of automotive components, through the reliable digital twin paradigm, trying to achieve "zero-anomaly" production in three principal areas: unit traceability, quality maximisation, and maintenance optimisation. - **FIBRATRAFIC** intends to create a new road traffic monitoring system based on three fundamental technologies: Fibre-based Distributed Acoustic Sensors (DAS), Signal processing techniques and Machine Learning.[73] - The Sendaviva nature park and the NAITEC technology centre will develop **a pilot test of VAIVEC**, an autonomous, electric, and energy-efficient vehicle created in Navarra. With this collaboration, both entities support sustainability and innovation through new, more intelligent, and environmentally friendly forms of mobility. - Since 2022, NAITEC set four technological platforms that define the roadmap of the Centre's technological strategy. These platforms revolve around Sustainability, Hydrogen, Digitalisation and New Materials.[74]

Source: Advanced Technologies for Industry Technology Centre Mapping, 2023 and NAITEC, 2023 https://www.naitec.es/

Box 2: Example Technology Centre: TEMA – Centre for Mechanical Technology and Automation (PT)

Name of the Centre	**TEMA - Centre for Mechanical Technology and Automation (PT)**
Location and scope	
The Centre for Mechanical Technology and Automation (TEMA) was founded in 1996 in Aveiro, Portugal. The main objective of TEMA is to do traditional research and development in mechanical engineering, while opening up to developing innovative technologies, such as nano and bio technologies in collaboration with different industries. TEMA is included in the "Portuguese Roadmap of Research Infrastructures of Strategic Relevance", having been classified by FCT (Foundation for Science and Technology) of the region.	
Main services and equipment	

[72] See https://www.naitec.es/en/infrastructure-and-equipment/urban-test-bed/
[73] See https://www.naitec.es/en/knowledge/projects/
[74] See https://www.naitec.es/actualidad-2/noticias/

TEMA provides the following services:

- **Fundamental and Applied Research.** TEMA supports research activities, both fundamental and applied research. it offers services in six main research lines:
  - Advanced mechanical engineering;
  - Applied energy;
  - Biomechanics;
  - Development of simulation software;
  - Nanoengineering;
  - Transport technologies.
- **Innovation, Technological Development and Technology Transfer to the Society**. The objective of this service is to support products and processes' development, and to improve the competitiveness of the clients in business areas such as:
  - The development of new computational tools;
  - The study and development of new materials and engineering systems;
  - Innovative engineering products, including biomechanical devices;
  - Innovative and/or improved manufacturing technologies;
  - Design of equipment and prototypes;
  - Nanoengineering applications.
- **Consulting, Training and Services**. This is a complementary service, with the objective to address the demands of the clients, as well as to offer expertise in the following areas:
  - Mechanical trials, essays, and prototypes;
  - Material characterisation at micro and nano scales;
  - Industrial automation;
  - Energy systems, energy efficiency and fluid mechanics;
  - Transportation systems' impact, environment, and life-cycle analysis;
  - Optimisation of manufacturing processes;
  - Moulding technology;
  - Specialised training and consulting.

To provide these services TEMA is equipped with laboratories such as the Mechanical Testing Laboratory, the Machining and Tribology Laboratory, the Nanotechnology Laboratory, the Computational Injury Biomechanics Laboratory, and the Materials Characterisation Laboratory, among others.

Recent projects related to the green and digital transition in mobility

- The aim of **CISMOB** is to create a "Cooperative information platform for low carbon and sustainable mobility" to boost innovative ways to reduce the carbon footprint, and to make urban areas more sustainable, for example, using the transport infrastructure through ICT.
- The **PriMaaS** project seeks to foster the integration of traditional collective transport forms with personal and innovative ones by creating equitable mobility services focused on citizens' needs. By using data gathered in real time, it will ensure more comfortable, affordable, and sustainable transport options with minimum carbon levels.[75]

[75] See https://www.ua.pt/en/tema/tema-newsletter

Source: Advanced Technologies for Industry Technology Centre Mapping, 2023 and TEMA, 2023 https://www.ua.pt/en/tema/

Box 3: Example Technology Centre: CEA Mobility Platform (FR)

Name of the Centre	**CEA Mobility Platform (FR)**
Location and scope	
CEA Mobility is one of the technological platforms of CEA Liten, located in Grenoble and Chambéry. The objective of these platforms is to innovate R&D products and processes as well as to provide companies the data and the know-how to make reliable products. More concretely, the Mobility Platform takes a system-level approach to solutions for mobility, from individual technologies to complete drivetrain systems. The Platform is structured in two units, which work together to advance towards carbon-free mobility: • The electric mobility unit integrates virtual and physical testing into hybrid battery and fuel cell systems for land, air, and maritime vehicles. • The MUSES unit has the objective to improve the performance, durability, and safety of the technologies to shorten time to market.	
Main services and equipment	
The electric mobility unit offers the following services: - Size and design of hybrid systems and energy management laws; - Testing in the lab or in the real world; - Validation and optimisation of electric systems (batteries, PEMFCs) using simulation and rapid prototyping on a hardware-in-the-loop bench; - Instrument vehicles, analysis of road test and usage of data on actual batteries. The MUSES unit provides the following services: - Developing modelling and simulation tools at different scales; - Designing and running specific experiments with the Battery and Fuel Cell Platforms; - Building and expanding a database of component properties and test results so that artificial intelligence algorithms can be implemented. - Developing multi-physics and multiscale simulation models and tools for Li-ion batteries, fuel cells, and proton exchange membrane electrolysers.	
Recent projects related to the green and digital transition in mobility	
• CEA-Liten improved and updated its dimensioning software for energy systems combining fuel cells and batteries. The new release should help make developing hybrid electric vehicles more efficient. • A 50 kW SOFC-type fuel cell was installed on board of the MSC Europa cruise ship in 2022. The project is financed by the French energy agency ADEME and marks a step toward making cruise ships more environmentally friendly.[76]	

Source: Advanced Technologies for Industry Technology Centre Mapping, 2023 and CEA Mobility Platform, 2023 https://liten.cea.fr/cea-tech/liten/english/Pages/Work-with-us/Technology-platforms/Electric-Mobility.aspx

[76] See https://liten.cea.fr/cea-tech/liten/english/Pages/Medias/News/

4. Investment and funding

Key findings

The EU27 mobility, transportation and automotive industrial ecosystem has seen **an increasing volume of venture capital investment.** The total investments in firms, which operate at late technological development stages, have **more than tripled since 2020** and reached a total **volume of over EUR 6 billion**. Investments in firms at earlier development stages and firms which are exiting the market have seen stagnating investment, with a volume of less than 1 billion each. By far the **most VC went into later developed technologies**.

Within the mobility ecosystem, the **VC volume of investment in autonomous vehicles has tripled since 2019** and reached an overall funding volume of more than 400 million in 2022. The **most active investors** in autonomous vehicle startups are Plug and Play Tech Center, Y Combinator, Maniv Mobility, Motus Ventures and Trucks Venture Capital.

The **EU27 mobility ecosystem lags behind in investing in highly capitalised startups**, i.e. so called unicorns with more than EUR 1 billion revenue. One of the few exceptions is the French company *Prophesee.*

Electromobility is becoming increasingly popular among consumers, which is also reflected in investment behaviour. Since 2020, the venture capital and private equity **investments in electric vehicles have doubled** and reached a capitalisation of **EUR 2 billion.**

Foreign direct investments of the EU27 mobility ecosystem **peaked in 2018** and declined until 2021. Since then, outside **EU27 foreign investments have been significantly below the level of the past ten** years and have not recovered yet. The inside and intra EU27 investments in the mobility ecosystem have also declined since 2018 but have recovered to the pre-pandemic level.

With regard to public procurement in the mobility, transportation and automotive industry, the **highest relative growth** in numbers of notices, within the green transition, stems from **hybrid vehicles** and **emission free technologies.** The **highest absolute growth** in the numbers of notices took place in **hydrogen** and **electric vehicles**.

4.1. Venture capital and private equity investments

Investment data has been captured from various sources including private equity investment, venture capital investment into new technologies, foreign direct investment and public procurement. The scale of venture capital (VC) and private equity (PE) investment in mobility tech startups has been calculated using data from the Crunchbase and the Net Zero Insights sources already presented above.

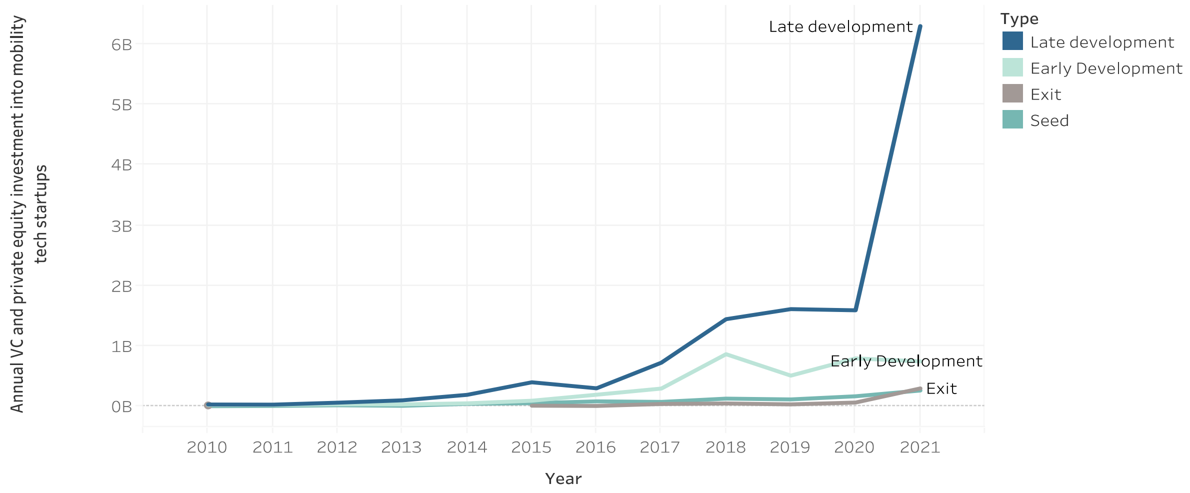
The analysis of Net Zero Insights and Crunchbase allowed to capture investment information for funding rounds of green and digital mobility tech companies. The investment figures presented in this section refer only to the funding rounds where a value has been disclosed. Those investments for which no values were published are therefore not included in the analysis.

Overall, there has been an increase in funding over the course of the last ten years in Europe's mobility, transport and automotive industry.[77] Although there has been, in general, a steady increase of PE and VC investment since 2018, they are not equally distributed. The majority of VC and PE funding into mobility tech companies were primarily

[77] https://www.eucar.be/industry-continues-to-invest-massively-in-rd/

absorbed by companies at late-stage development. On the other hand, access to early and seed-stage VC funding has been declining since 2018. Especially investments in early-stage startups exhibited a strong decline in 2018, which was largely offset again in the following year.[78] The largest investment growth, and also the largest investment volume, was accounted to late-stage startups. Annual VC investment in late-stage development has more than tripled since 2020, reaching a total volume of over EUR 6 billion. This development indicates the rising interest in mobility solutions at late development stages and a rather stagnant, yet relevant interest in earlier stages. The results are consistent with the role of VC, which increases to flow in startups at higher development stages.

Figure 26 Annual funding in mobility tech companies since 2010

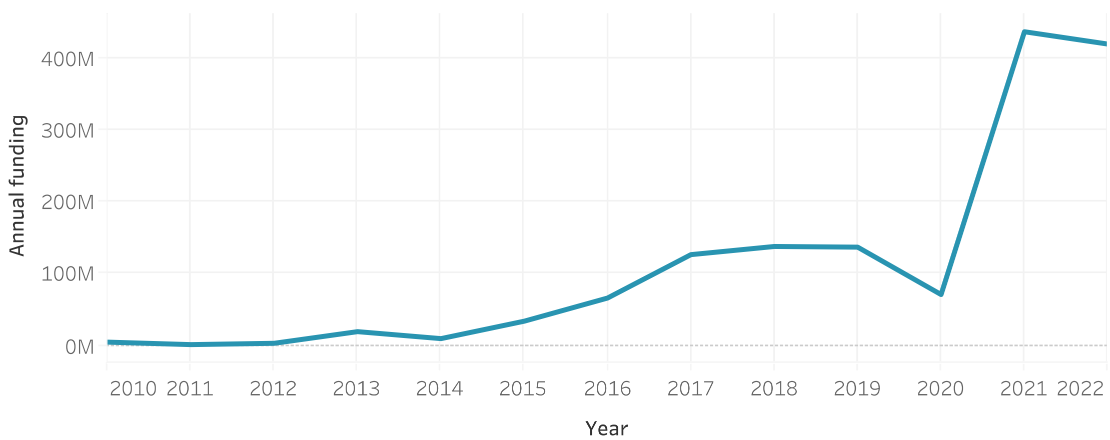


Source: Technopolis Group calculations based on Crunchbase, 2022

Autonomous vehicles

The autonomous vehicles sub-industry is an active field for investors, receiving funding of more than EUR 400 million in 2022. It is important to highlight that funding in autonomous vehicles has tripled since 2019 after a brief decline in 2020. In general, the increase in autonomous vehicle funding is in line with the overall automotive industry development. The most active investors in autonomous vehicle startups are Plug and Play Tech Center, Y Combinator, Maniv Mobility, Motus Ventures and Trucks Venture Capital.

Figure 27 Annual funding in autonomous vehicles since 2010



[78] https://www.acea.auto/figure/rd-investment-in-the-automobile-sector-by-world-region/

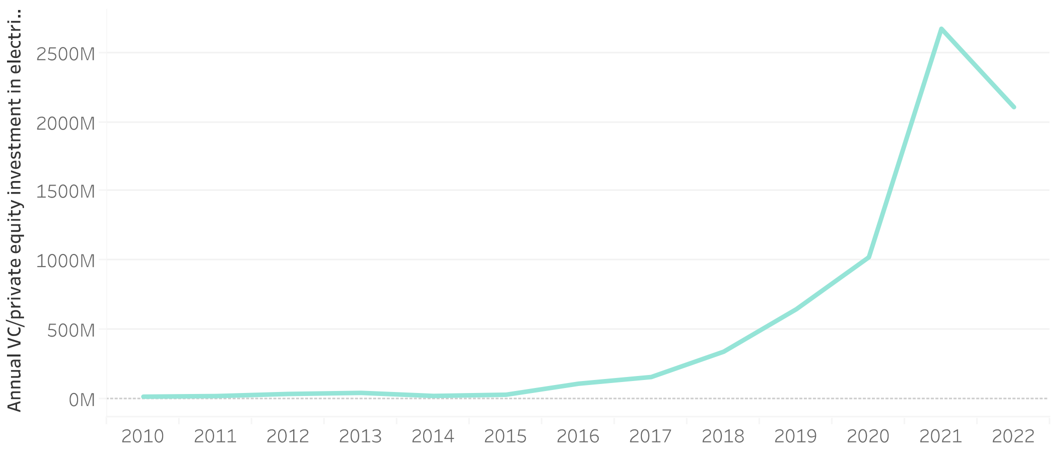
Source: Technopolis Group calculations based on Net Zero Insights, 2022

Compared to the US, the EU27 lags behind in investing in highly capitalised startups, i.e. so called unicorns with over a billion in market valuation. However, there is potential to close this gap because some European startups are coming close to a billion Euro valuation, such as the French company Prophesee. Prophesee's computer vision systems open new potential in areas such as autonomous vehicles, industrial automation, IoT, mobile and AR/VR. One early application was in medical devices that restore vision to the blind. It remains to be seen whether Europe can close the gap with the US and catch up, and raise the investments in highly capitalised companies such as Prophesee.

Electric vehicles

The European electric vehicle industry represents one of the largest sub-sectors in the automotive sector, which has also seen strong investment growth in the past. **Ten years ago, the sector was almost insignificant for investors and received hardly any funding, but that has changed dramatically in the recent past**. In 2022, venture capital and private equity investments in electric vehicles has increased more than twenty-fold to over EUR 2 billion per year in the last eight years. The increasing availability and popularity of electric vehicles, a rising acceptance among consumers and an increasingly available electric charging infrastructure have reinforced the upward trend.

Figure 28 Annual funding in electric vehicles since 2010



Source: Technopolis Group calculations based on Net Zero Insights, 2022

One good example is the company Tesla as one of the most capitalised companies in the world. As pioneer in the field, Tesla increases the attractiveness of other startups in the same industry as well. Generally, as core technologies in the field of electric vehicles have been increasingly establishing, it raises the popularity of electric vehicles among investors. However, there is a clear slump in 2022 indicating that the electric vehicle sector has been heavily influenced by the geopolitical and global environmental developments, such as supply chain and material shortages caused by the pandemic or wars and shrank compared to the previous year.

4.2. Foreign direct investment in automotive and transportation

fDi intelligence[79] tracks cross-border greenfield investments in EU considering both directions inward and outward. It provides real-time monitoring of investment projects, capital investment and job creation statistics with powerful tools to track and profile

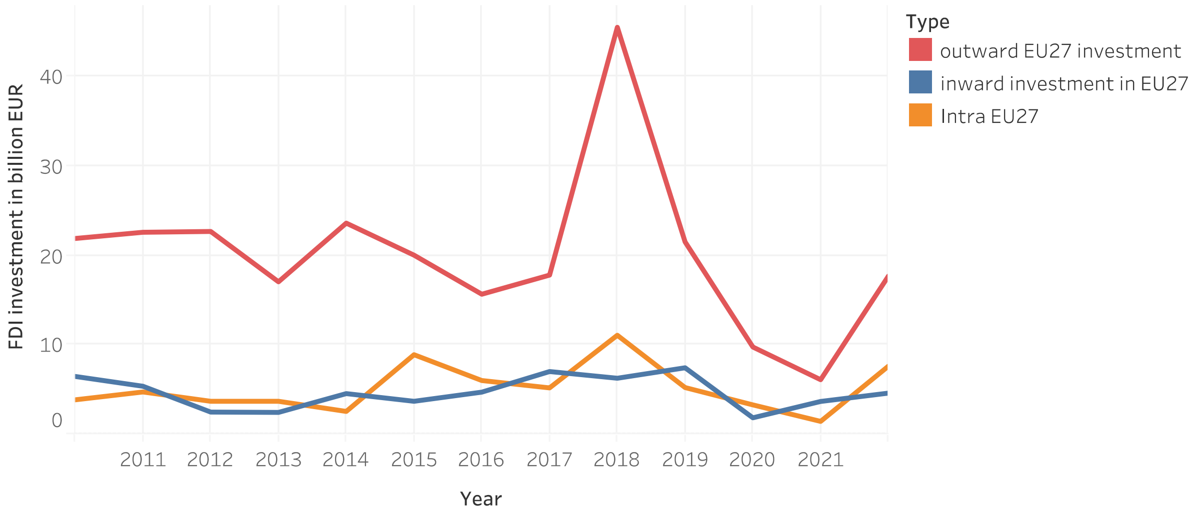
[79] https://www.fdiintelligence.com/

companies that are active investors in the field. Nevertheless, it excludes mergers and acquisitions (already part of the VC data analysis above).

Until 2018, the European mobility, transportation and automotive industry was actively investing abroad (see red line) and solidified its global value chains and position as a global player (see Figure 29). The increasing trend reached its peak in the period before the Covid-19 pandemic, particularly between 2017 and 2018, followed by a rapid drop, particularly in the first two years of the pandemic. Since then, the EU27 countries' outward foreign investments have been significantly below the level of the past decade's average and not fully recovered since.

In 2021, however, the negative trend arrived at a turning point when the industry started to invest more actively abroad again. As a result, the EU's outward foreign investment grew again for the first time since 2021, although it remained below the pre-pandemic level of investment. Obviously, both geopolitical turbulences since 2018 and the pandemic itself had a massively negative impact on the foreign investment and global interconnectedness of the EU mobility ecosystem. Although the pre-pandemic level of investment has not yet been reached, the European mobility, transportation and automotive sector remains an active investor abroad. This development illustrates that European mobility ecosystems' foreign investments are highly dependent on the global environment and fluctuate strongly depending on current circumstances.

Figure 29: Foreign direct investment in the mobility sector



Source: Technopolis Group calculations based on fdiInsights, including the following industries automotive components, automotive OEM and transportation

In contrast to outward foreign investment, intra-European mobility investments (see orange line of Figure 29) are at an overall lower level having moved mostly in tandem with outward foreign investment since 2011. However, in contrast to the outward foreign investment figures, the downturn was not quite as great as in the case of foreign investment and has already reached the pre-pandemic level of 2017. Thus, one can conclude that the domestic (European) mobility ecosystem investments are more resistant to global shocks.

The inflow of capital from outside the EU27 into the ecosystem, represented by the blue line in Figure 29, exhibits a comparable trend to intra-European investments. However, a slight divergence in trends appears to have emerged since 2021, with foreign capital inflows experiencing notably slower growth compared to both intra-European investments and outward foreign investments.

The notable growth trends across all three investment categories of recent years signifies a general, as well as a recently growing, availability of funds for investments within the ecosystem. These investments are likely to also benefit the uptake of green and digital technologies and hence foster the twin transition of the mobility sector. This finding, of a general availability of investment capabilities, is corroborated by the results of the EMI survey, which found that also a large fraction of the SMEs active in the mobility ecosystem had increased their investments in green and digital technologies in the past five years. Hence, supporting the hypothesis that these increased investment activities are highly relevant for the twin transition of the mobility sector as well.

4.3. Public procurement supporting the digital and green transition of the mobility ecosystem

Public authorities have the capability to contribute to transformation of markets resulting from their high purchasing power. Namely, through innovative public procurement governments can foster the uptake of innovative goods and services, like for instance environmentally friendly goods, solutions and services, or digital technologies. Thereby, they are able to accelerate significantly the green and digital transition of economies.

To monitor the twin transition in public procurement in the field of the entire ecosystem, we based our analyses on the Common Procurement Vocabulary (CVC) classification system and keywords. We focus thereby on green and digital products, goods or services that were procured by public institutions. The main source for this analysis has been the Tenders Electronic Daily, the online version of the 'Supplement to the Official Journal' of the EU, dedicated to European public procurement. The period in focus from 2015 until today allowed an analysis over time including up to date information.

The analysis indicates that the value of **public procurement in the mobility domain** was the main object of procurement in EU 27 countries, amounts to EUR 5.9 billion in the period 2015-2020. Public procurement in the **sphere of twin transition** amounts to EUR 11.8 billion representing 0.2% of the total procurement value on mobility, which is in turn 7.7% of the total number of notices published.

The results show also that **green transition** accounts for 0.2% of total procurement value and 7.5% of the total number of published notices. The value of notices procured by governments regarding the **digital transition** is close to 0% while the notices published in digital transition correspond to 0.3% of the total number of notices published.

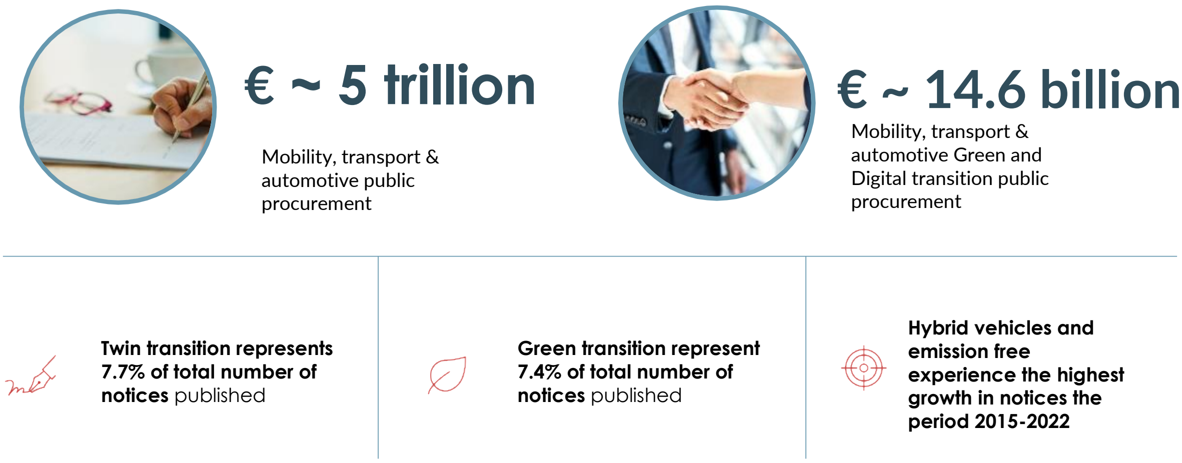
The most notable growth in numbers of notices in the field of green transition stems from **hybrid vehicles** and **emission free technologies** with an average annual growth of 60% and 53% respectively. In terms of absolute value, there was a considerable growth in hydrogen and electric vehicles with very high average annual growth rates of 386% and 196% respectively in the period 2015-2022.

The analysis shows that **navigation systems** and **semiconductors** have the highest increase in notices for digital transition with an average annual growth of 32% and 17% respectively. Navigation systems have an observed average value growth of 98%. The main government function, under which the largest expenditures were made, was the field of **general public services** with 20.54%. In contrast, the field of **environment** accounts for approximately 5% of expenditures in the period 2015-2022.

Among all references, **electric vehicles**, Euro 6 engines and hydrogen technologies were the most common references made in notices covering construction as an object of procurement. **Hydrogen technologies** are often found to be the main requirement of the notices. A typical request for a variety of vehicles, which can range from a single car, a fleet, and buses to trains, requires the use of hydrogen as a fuel. Another important requirement to win a contract is the **Euro 6** engine standard. A notice usually specifies that applicants' vehicles should be able to fulfil at least the Euro 6 standard and above. Another common feature of the procurement notices is the **specification of electric vehicles**, which applies to a wide range of different vehicles and applications. However, the electric vehicle specification is mostly found in procurements considering public transportation vehicles.

With regard to the **digital transition** in the public procurement of construction, notices on **navigation systems** and **5G** are frequently found as objects of procurement. More specifically, navigation systems are usually a required technology in vehicles, which is also commonly found in a variety of vehicles. Furthermore, 5G is currently an often-required communication technology for vehicles or transportation signals, such as railroad signs and traffic crossings.

Figure 30: Public procurement in the field of mobility



Source: Technopolis Group based on TED

5. Skills demand and supply

Key findings

New competences and skills in the mobility ecosystem are becoming increasingly important as the transportation sector is transforming and becoming more sustainable and technology driven. With the spread of electronics and software used in vehicles, related skills in digitalisation, robotics or Internet of Things are more and more important.

Monitoring trends in green and digital transition related skills also hints to technology uptake and the transition of the industry itself. **As found by the analysis of LinkedIn data, 15% of professionals employed in the mobility, transportation and automotive industrial ecosystem possess advanced digital skills**, **while 4% have green skills**. Hence, there are **three times more digital professionals** than **green professionals**.

Green professionals are particularly often employed in the field of **circular economy**, **low carbon technologies**, **energy saving technologies**, and **renewable energy**. Digital professionals are mostly employed in the sphere of **Internet of Things**, **cloud**, and **artificial intelligence**, followed by robotics, cybersecurity and big data.

The car manufacturing and automotive industry is actively employing green and digital professionals. Especially Germanys' two largest automotive suppliers, **Bosch** and **Continental, employ the largest share of digital and green professionals**.

With regard to **growth in competences**, an increase in green professionals can be observed above all related to **batteries**, the **circular economy** and in **recycling technologies.** Experts with solid knowledge in the field of green and resource-friendly usage of materials are therefore in high demand.

The **fastest growing skills** in the automotive, transportation and automotive ecosystem are **commercial skills, data analysis skills**, and **analytical skills**.

In summary, the mobility ecosystem **must continue to invest in green and digital skills** to remain competitive in the changing landscape of transportation.

The main skill related challenges for SMEs in the mobility sector pertain to four factors: 1) a **supply and demand gap for** workers equipped with the **required skillsets**, 2) the extreme **diversity of skillsets required for a successful transformation**, 3) a **lack of practical experience** of young professionals leading complex transformations, 4) **missing change management skills**.

This section aims at analysing trends in the supply and demand of skilled professionals relevant for the green and digital transition based on the LinkedIn data. Since there is a general lack of data about specific digital and green skill sets specific to industries, LinkedIn offers unique insights despite its limitations and diversity in usage. The LinkedIn network is the largest professional platform with a wide variety of information about their users, like profile summaries, job titles, job descriptions and fields of study. We used the platform for identification of skilled professionals in advanced technologies, especially in the field of digital and green transition. It represents the single most comprehensive source currently available for the construction of technology-specific skills related indicators.

In order to analyse the number of professionals working in the ecosystem, we focused on occupations with a high relevance for mobility sector . In this process, green skills have been identified as skills relating to: environmental protection, environmental services, low carbon technologies, renewable energy, the circular economy and clean production technologies and business models areas. Advanced digital skills have been defined in the context of key digital technologies captured in certain projects, notably in projects related to artificial intelligence, cloud computing, connectivity, robotics, Internet of Things, augment and virtual reality and the blockchain technology.

5.1. Supply side: professionals in mobility with green and digital skills

The mobility, transportation and automotive industry is undergoing a significant transformation as new technologies and digitalisation are changing the way vehicles are designed, produced, and used. The development and **implementation of green and digital skills are essential for the success of the automotive industry** in this new era. Some of the ways that green and digital skills are impacting the automotive industry include **connected vehicles**, **electric vehicles**, and **autonomous vehicles**.

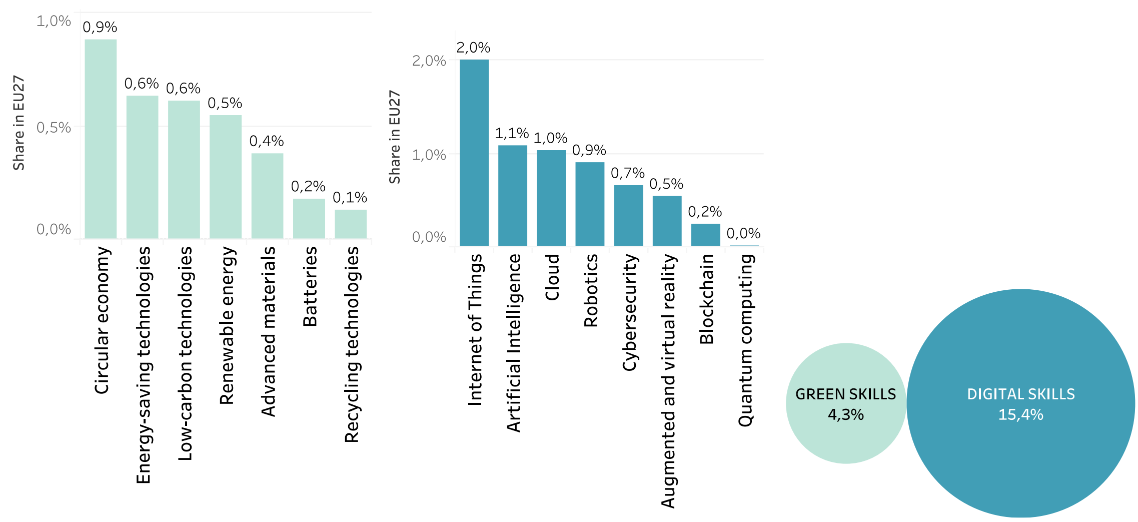
The popularity of connected vehicles is rapidly growing, and the integration of these vehicles into the broader transportation system relies heavily on the development of digital skills. It is crucial to prioritise the acquisition and implementation of new digital technologies such as telematics, infotainment systems, and advanced driver assistance systems. Additionally, the design and production of electric vehicles necessitate the utilisation of cutting-edge software and digital tools, along with a comprehensive understanding of battery technology and energy management systems. Green skills play a pivotal role, particularly in the procurement of battery materials and in establishing effective recycling practices. Similarly, the design and production of autonomous vehicles demand the application of sophisticated software and algorithms, as well as a deep comprehension of artificial intelligence and machine learning concepts. By prioritising the development of these skills, we can drive innovation and ensure the successful integration of autonomous vehicles into our transportation systems.

The analysis of the LinkedIn data provides some interesting insights about the availability of green and digital professionals in the ecosystem in EU27 countries. Figure 15 shows the share of professionals with green skills and digital skills. Moreover, in the right part the shares of both skill categories in overall pools of skills are presented.

Within the registered professionals on LinkedIn employed in the automotive and transportation industries, professionals with **green skills** are most often required in the sphere of energy transition and sustainable energy production. Interestingly, the data indicates that, nevertheless, only **4.3%** of the total jobs in the industrial ecosystem involves **green skills**. The highest share of green professionals is observed in the area of **circular economy** (which is an aggregate category including recycled materials or recycling among others), with more than 0.9%. Furthermore, green professionals are also particularly often employed in the field of **low carbon technologies**, **energy saving technologies** and **renewable energy**, with over 0.3% of the total share in the ecosystem.

On the other hand, the LinkedIn data indicates that **15.4%** of mobility professionals have advanced **digital skills**. Hence, companies tend to have three times more professionals with digital skills than green professionals among professionals in the mobility, transportation and automotive ecosystem. Digital professionals are mostly employed in the sphere of **Internet of Things**, **clouds**, and **artificial intelligence**, followed by **robotics**, **cybersecurity** and **big data**.

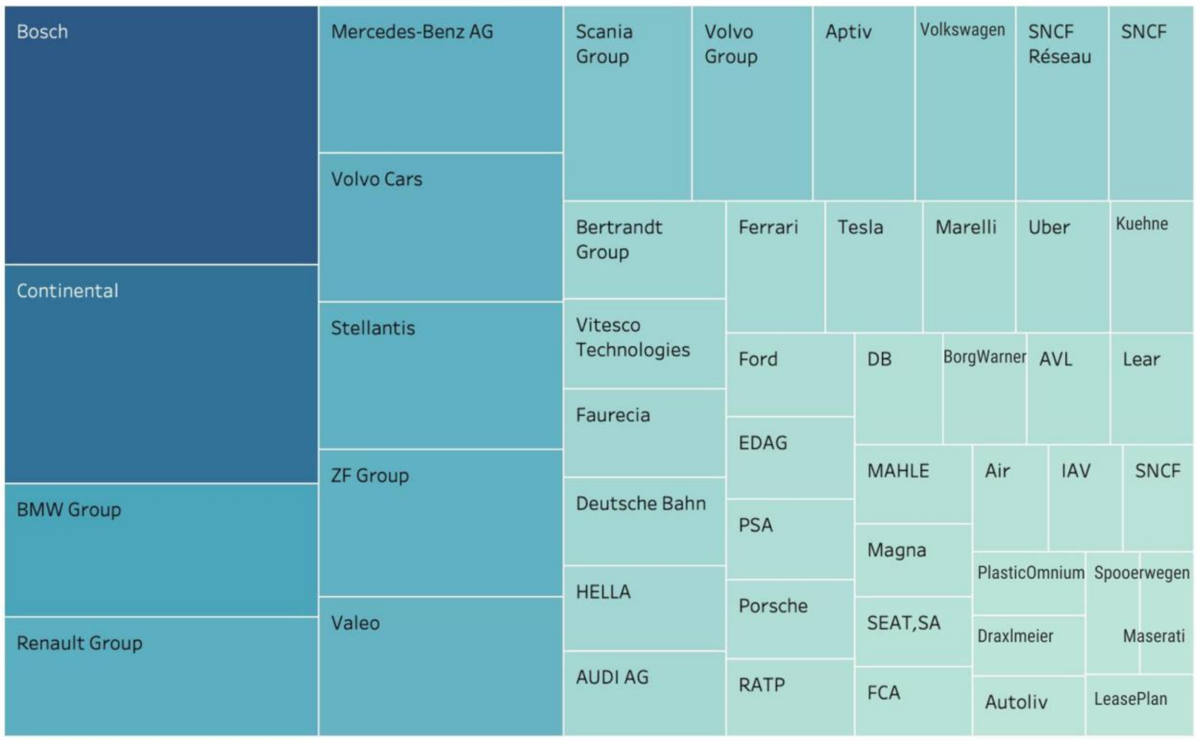
Figure 31: Share of professionals with green and digital skills



Source: Technopolis Group calculations, 2022

The LinkedIn data also shows some indication on which companies employ the largest proportion of green and digital professionals combined. Figure 32 illustrates the combined distribution of green and digital skills among companies operating in the mobility ecosystem.

Figure 32: Top 100 mobility companies with the highest share of both digitally and green skilled workers



Source: Technopolis Group calculations, 2022

We see from the figure that Germanys' two largest automotive suppliers, Bosch and Continental, employ the largest share of digital and green professionals. Similarly, large proportions of professionals are employed at major European car manufacturers, such as BMW Group, Renault Group, Mercedes-Benz AG and Volvo Cars. The large proportion of green and digital experts in the mobility and automotive sector is intuitive, since digitalisation is one of the main topics and development paths of these industries, which are being actively pursued. Consequently, there are many green and digital professionals in these sectors. For example, Bosch operates its own digitalisation department, where innovative tools and business models are developed, tested and finally made ready for market entry.

In the group of top employers of green and digital professionals there are also well-known transportation companies like the Deutsche Bahn (DB), SNCF or Air France. Although in comparison with the leading grout they represent a rather smaller share. A higher degree of digitalisation and the increased environmental friendliness of railway companies has been pursued for years. Deutsche Bahn, for instance, is increasingly using digital tools to monitor rail traffic, ensure operational readiness and minimise train cancellations. Thus, an increasing number of green and digital professionals are being sought in this sector.

Progress over time

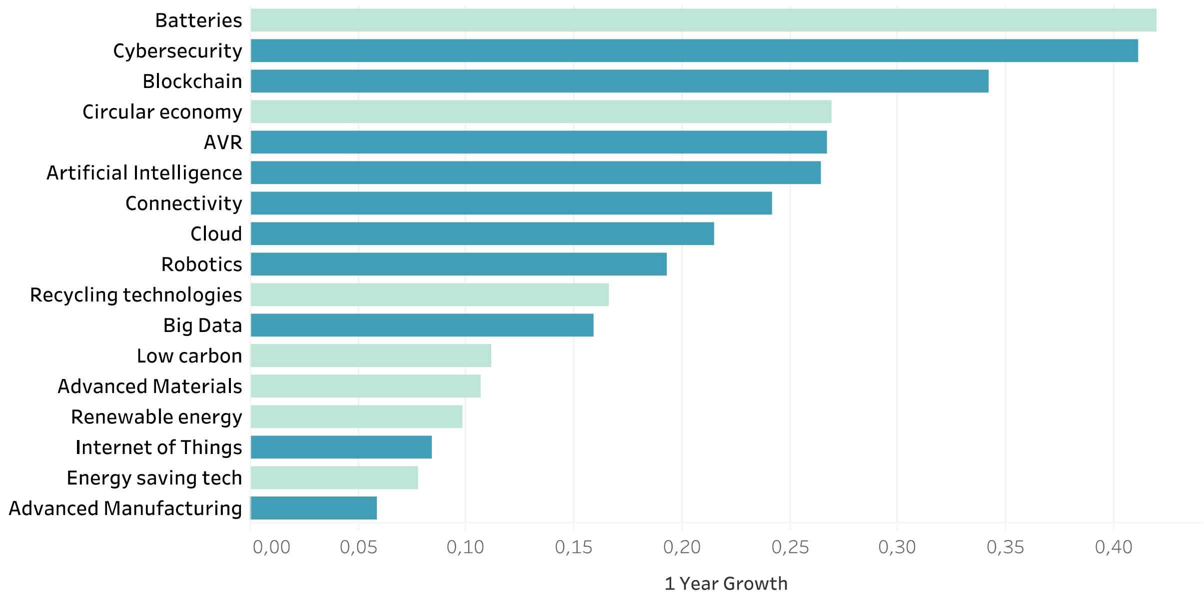
To understand the significance of the change in the number of professionals with digital or green skills, it is important to consider the broader employment trends. As mentioned earlier, the overall count of professionals in the mobility, transport, and automotive ecosystem on LinkedIn decreased between 2020 and 2021. However, there has been a slight increase of 0.8% in 2022. In contrast, the proportion of professionals possessing digital or green skills has consistently grown over the past few years. These skills have been identified and validated by industry experts, reflecting the evolving demands of the industry. By analysing the identified industry-specific skills, we can identify the technological skills that have experienced the highest growth among professionals in the mobility, transportation, and automotive sector.

With regard to **green competences**, an increase in green professionals can be observed above all in the **battery sector**, in the **circular economy** and in **recycling technologies.** In these three technologies, material scarcity, reusability and eco-friendliness play a crucial role and require special expertise. Experts with solid knowledge in the field of green and resource-friendly usage of materials are therefore in high demand. For example, in battery production, the sustainable flow of recyclable battery components and raw materials is essential. For this, a deep understanding of green production processes is imperative. Furthermore, the end-of-life of a battery plays a major role in recycling technologies so that raw materials can be extracted for further production. In the circular economy, it is also extremely important to have a holistic understanding of which materials are used in production, how environmentally friendly they are and how to make them as reusable as possible in their entirety in order to release as little waste as possible into the environment.

With regard to digital technology related skills, the analysis identified the highest growing field. Especially technology skills in the area of **cybersecurity**, **blockchain technology** and **AVR** have seen the largest increases among professionals in the mobility ecosystem. This is due to the fact, that these three sectors have seen an increase in public interest over the past years, which also reflects in a higher demand for digital skills in general. Overall, the increase in green and digital experts in the mobility, transportation and automotive ecosystem is moderate and fluctuates between 0.05% and 0.5%.

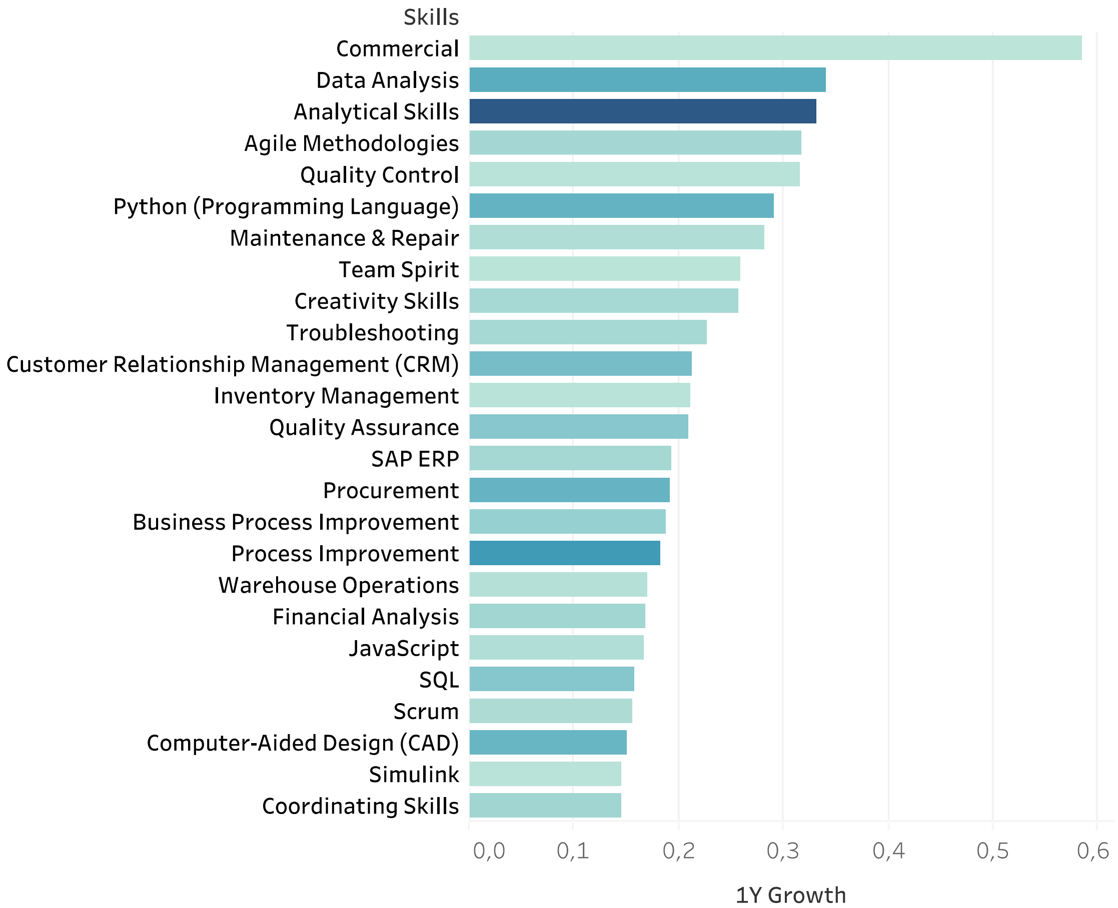
When it comes to the **fastest growing groups of skilled employees** in the automotive, transportation and automotive ecosystem, there is a strong presence of **commercial skills, data analysis**, and **analytical skills** are on top of the chart. Figure 34 provides an insightful overview on all skills exhibiting the largest growth in the last year. Note that the darker shaded bars indicate a higher share of LinkedIn users for a particular skill, i.e. towards blue, while a brighter shade, i.e. towards green, indicates a smaller share of LinkedIn users. It is also important to explain that we extracted the skill definitions solely using LinkedIn descriptions.

Figure 33: Highest growing share of professionals with specific technological skills among professionals employed in the mobility industrial ecosystem



Source: Technopolis Group calculations, 2020 and 2022

Figure 34: Skills that have increased the most on the profile of professionals employed in the mobility, automotive and transport industries on LinkedIn



Source: Technopolis Group calculations, 2020 and 2022

The analysis reveals a significant surge in the demand for proficiency in (data) analytics, as well as a substantial growth in various programming languages, notably Python and JavaScript. Furthermore, there is an increasing need for enhanced organisational skills, including quality control and assurance, inventory management, procurement, and the (business) process improvement and management domain.

Our analysis reveals that digital professionals exhibit a heightened level of analytical and programming proficiency. Moreover, they possess a diverse array of organisational, interpersonal, coordination, and managerial skills, including quality control, creative aptitude, agile methodologies, and inventory management. Additionally, there is an escalating demand for personal skills, such as teamwork and creativity.

5.2. Demand for green and digitally skilled employees

Skills demand in the tourism industrial ecosystem has been analysed following the skills intelligence insights of Cedefop, the European Centre for the Development of Vocational Training[80]. This dataset covers all EU27 countries (plus the UK) and is based on the collection and analysis of more than 530 online job advertisement sources (424 distinct websites) which are open-access sites. The dataset provides information on most requested occupations and skills across European countries based on established international classifications, e.g., ISCO-08 for occupations, ESCO for skills, and NACE rev. 2 for sectors.

Specific to the mobility industrial ecosystem[81], there were **1 566 678 unique job advertisements** from companies between 2019-2022 in the EU27. These job advertisements have been extracted via text-mining and the required skills analysed from the perspective of the green and digital transitions. The pre-defined green skills are from ESCO v1.1 and the digital are predefined from ESCO v1.1.1 which is currently being updated. The European multilingual classification of Skills, Competences, Qualifications and Occupations (ESCO) is used as follows:

- **Green transition related skills** (ESCO v1.1.) are those knowledge and skills which reduce the negative impact of human activity on the environment.
- **Moderate and Advanced Digital skills** (ESCO v1.1.1 which is currently being updated) are competences which involve the confident, critical and responsible use of, and engagement with, digital technologies for learning, at work, and for participation in society. Within digital skills, we distinguish between moderate digital skills (that do not include basic Microsoft office skills but include specialised software used in the industry, the use of statistical software etc) and advanced digital skills (a category that is filtered for digital technologies highlighted in the methodological report including AI, big data, robotics, IoT, cloud, augmented and virtual reality, blockchain).

The share of online job advertisements that required any form of **moderate digital skills (excluding basic IT office skills) was 23.32%** over the period from 2019-2022, while this percentage was **11.76% for advanced digital skills.** Requirements related to the **green transition** appear much less often on the advertisements notably in **1.96%** of the cases.

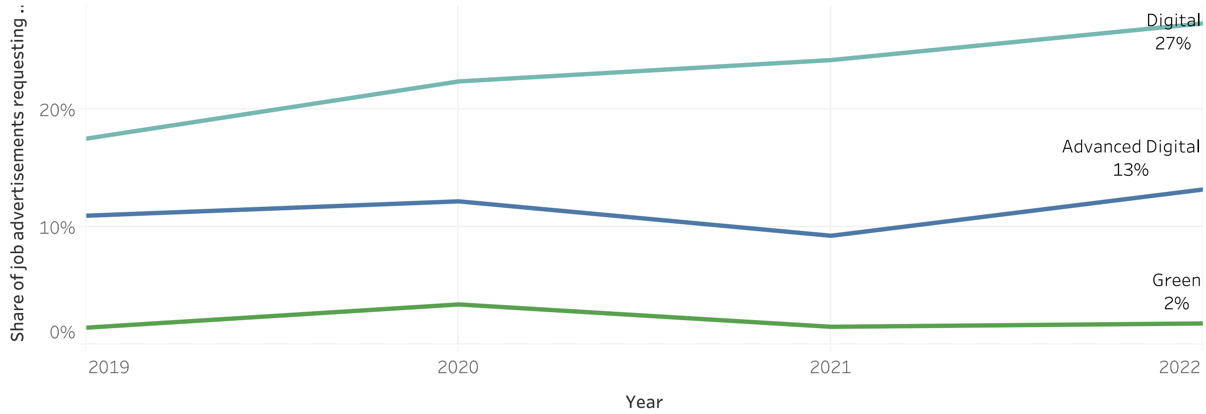
It is interesting to observe that the share of digital transition related job ads continued to grow after 2020, as long as the share of job ads that requested and advanced digital skills had a slight drop in 2021 and started to grow again in 2022. The share of job ads with a demand for green transition related skills stayed more or less stable over the period from 2019 to 2022.

---

[80] https://www.cedefop.europa.eu/en/tools/skills-online-vacancies

[81] As defined by the NACE codes in the Annual Single Market Report 2021

Figure 35: Share of online job advertisements that demand digital and green transition related skills within the total number of job advertisements in the mobility industrial ecosystem



Source: Technopolis Group calculations based on Cedefop data, 2023

The more sought after advanced digital skills include the following:

1. Computer programming
2. Classification of databases (their purpose, characteristics, terminology, models and use such as XML databases, document-oriented databases and full text databases)

ICT system programming.

The more sought-after green skills are:

1. Energy efficiency
2. Corporate social responsibility in terms of economic responsibility towards shareholders as equally important as the responsibility towards environmental and social stakeholders. This is probably linked to snippets of company advertisements where the company values are described.
3. Emission standards and environmental legislation.

Based on thorough desk research and insightful interviews with mobility ecosystem experts, we have dissected the pressing skill-related challenges faced by companies. As discussed earlier, the mobility sector is facing a rapid pace of technological and market dynamics. The continuous influx of innovations, from electric and autonomous vehicles to rapid smartification, creates substantial challenges for companies with respect to their workforce, particularly the smaller ones.

The first major challenge revolves around the ever-advancing socio-technical and market developments. **Keeping their workforce current** is a formidable task for companies in the mobility ecosystem. This challenge is further exacerbated by the **significant demand for skilled professionals** in the green and digital aspects of the sector in Europe, which outpaces the current supply. Attracting and retaining young talent while diversifying the workforce necessitates substantial investments in ongoing learning and development. Unfortunately, this poses a more significant obstacle for smaller and medium-sized companies, which are often not able to offer the same attractive salaries as their larger counterparts, making it difficult to compete for top talent.

The second challenge lies in the **diverse array of skills required for a successful green and digital transition** in the mobility sector. From traditional mechanical and electrical engineering to cutting-edge digital technologies like AI, data analytics, and advanced materials science, the demand for individuals with these proficiencies is high. Identifying individuals possessing these skills, who can effectively implement them, is a daunting task. Furthermore, providing training to existing employees in these new fields proves challenging, given the constraints on their time due to their ongoing work responsibilities, especially for smaller companies with limited capacities.

Thirdly, the dearth of **practical expertise and knowledge among fresh graduates and young professionals compounds the challenges.** With a growing emphasis on sustainability, employees need profound comprehension of green technologies, renewable energy systems, and environmental impact assessment, applying this knowledge across various aspects of the business. Simultaneously, the integration of digital technologies within the mobility sector is pervasive, requiring employees to be digitally literate to contribute effectively.

Fourth, the transition to greener and more digital systems often **necessitates change management skills**. Employees must adapt to new processes, technologies, and ways of thinking. Effective communication and stakeholder engagement are pivotal in managing this transition seamlessly. Surprisingly, our analysis indicates that the challenge of finding employees with these soft skills is relatively less problematic than the shortage of technical skills.

In conclusion, the skill challenges faced by the mobility sector in Europe during the green and digital transition are significant but manageable. Companies and educational institutions must collaborate to develop comprehensive training programs, foster innovation, and create an environment conducive to lifelong learning. Additionally, companies should explore strategies to attract talent from other industrial segments, such as IT, service, and manufacturing, to bridge the skill gap. This collective effort will drive the sector forward, ensuring a successful and sustainable transition.

6. Sustainable competitiveness: the green performance of the ecosystem

Key findings

The mobility, transportation and automotive industry **consumes a significant volume of natural resources, including fuel, water, materials, land and energy**. Regarding raw materials, the industries' demand is particularly high for steel, aluminium, and plastic. However, firms have many possibilities to realise resource-saving production and their transportation operations. The transition of the mobility ecosystem towards more sustainable production and consumption patterns should be supported by **monitoring and evaluating the use of resources** by the industry.

The **extraction of raw materials, the emission of particulate matter, and the negative impact on biodiversity** by the mobility, transportation and automotive industry **have increased** in recent years.

In terms of **greenhouse gas emissions of CO2** (measured in tonnes), the mobility ecosystem is above **the global average** and it is the second industry after agri-food emitting the most C02. With regard to particulate matter, there has been no decrease in PM10 and PM25 emissions over the last ten years. Rather the contrary is the case, particulate emissions from the mobility, transportation, and automotive sector reached a peak in 2021 and is likely to continue to grow. Although material extraction declined between 2011 and 2015, it has risen sharply since 2016, reaching an all-time high in 2020. The material extraction by the mobility, transportation and automotive industry is well above the global average.

Figure 36: Environmental impact summary table

Environmental impact	Change from 2010 to 2021 CAGR
GHG emissions	-0.2%
Material use	constant
Land use	+3%
Water use	+2.1%
Damage to biodiversity	+3%

Source: Technopolis Group calculations based on Exiobase, 2023

The efficient utilisation and management of resources within the mobility, transportation, and automotive ecosystem is an urgent concern, given the ever-increasing global demand for transportation. This ecosystem is heavily reliant on a substantial volume of natural resources, such as fuel, water, materials, land, and energy. Consequently, it becomes imperative to cultivate a deeper comprehension of resource consumption patterns within this ecosystem, and to effectively monitor and assess the industry's resource utilisation. Therefore, gaining insights into the practical realisation of resource consumption within the mobility, transportation, and automotive sector holds significant importance.

In order to minimise **fuel consumption**, companies operating within the ecosystem are actively investing in alternative fuel sources such as electricity, hydrogen, and biofuels. Moreover, enhancing vehicle efficiency through the implementation of hybrid and electric engines, as well as optimising aerodynamics, can significantly contribute to reducing fuel consumption. When it comes to **water consumption**, car manufacturers and transportation providers can implement more water-efficient practices, such as using waterless cleaning technologies and investing in water-efficient production processes. The **companies in the ecosystem also consume significant amounts of materials**, including metals, plastics, and other materials used in vehicle production. To reduce materials consumption, transportation providers implement more sustainable production practices, such as improved recycling and using renewable or biodegradable materials. **Land use** is another resource consumed, particularly in the construction of transportation infrastructure such as highways and rail lines. To reduce land use, mobility and transportation providers can invest in alternative transportation modes that require less infrastructure, such as biking or walking. Additionally, companies in the mobility ecosystem can also invest in more efficient land use practices, such as urban planning that prioritises public transportation and pedestrian-friendly spaces. Finally, **energy consumption** is a significant issue in the mobility ecosystem, particularly in the context of climate change. To reduce energy consumption, firms invest in energy-efficient technologies and practices, such as using renewable energy sources and improving the energy efficiency of vehicles and transportation infrastructure.

The green transition and transforms towards a more sustainable and environmentally friendly future of transportation and mobility involves moving away from fossil fuels and other unsustainable practices and towards cleaner sources of energy, more efficient use of resources, and more sustainable production and consumption patterns. Hence, **monitoring and understanding the use of resources is a key measure for environmentally friendly mobility**. In this section, we aim define and measure the trends in the above-mentioned environmental impacts

First, it is necessary to gain a **brief overview of the emissions created, the resources consumed, and the energy used in the mobility ecosystem**. As the world becomes more aware of the impact of transportation on the environment, there is a growing emphasis on reducing emissions in the mobility ecosystem. This is being achieved through a variety of means, including the use of cleaner fuels, the development of more efficient engines, and the promotion of sustainable transportation options such as walking, biking, and public transportation. Additionally, the growth of electric vehicles is providing a way to reduce emissions in the mobility ecosystem, as they do not produce tailpipe emissions and can be powered by renewable energy sources.

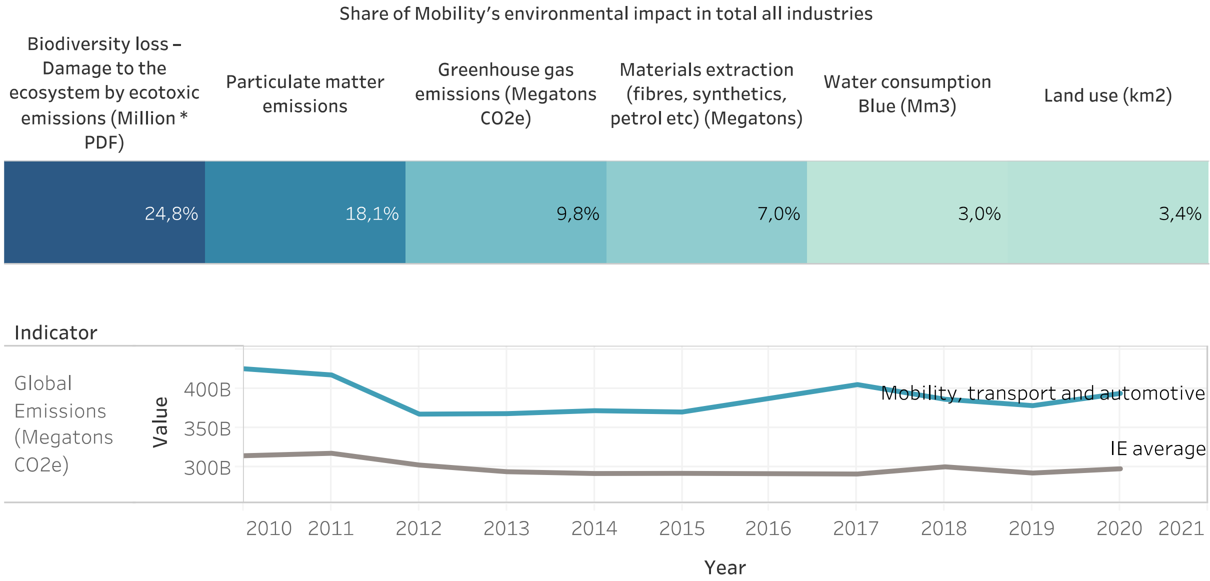
The mobility, transportation and automotive industry **is one of the major contributors to global resource consumption, both in terms of raw materials and energy**. Regarding raw materials, the industries' demand is particularly high for steel, aluminium, and plastic. When it comes to **energy consumption**, the mobility ecosystem needs a lion's share for **manufacturing, operations and maintenance**.

In order to evaluate the green transition, it is essential to monitor the progress of the transition. The data to monitor the green transition is drawn from the Eurostat and Exiobase 3.8[82] data sources. Whilst Eurostat represent the official European statistics,

[82] Exiobase is a time series of environmentally extended multi-regional input-output (EE MRIO) tables. Its coverage is by country and industry from 1995 to 2021 and has EU and extra rest of the world coverage. Source: Stadler, Konstantin, Wood, Richard, Bulavskaya, Tatyana, Södersten, Carl-Johan, Simas, Moana, Schmidt, Sarah, Usubiaga, Arkaitz, Acosta-Fernández, José, Kuenen, Jeroen, Bruckner, Martin, Giljum, Stefan, Lutter, Stephan, Merciai, Stefano, Schmidt, Jannick H, Theurl, Michaela C, Plutzar, Christoph, Kastner, Thomas, Eisenmenger, Nina, Erb, Karl-Heinz, … Tukker, Arnold. (2021). EXIOBASE 3 (3.8.2) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.5589597

Exiobase is a legitimate source of information referred to for example by the European Environmental Agency[83], the EC/JRC community[84], Eurostat[85], and by the European Commission to propose the regulation on carbon border adjustment mechanisms[86]. Pressure to environments refer to trade-embodied resources utilisation, and trade-embodied impacts. Resources utilisation is captured with **four main dimensions** which are considered in cross-industry comparisons. The four dimensions are namely, embodied land use, water consumption, material consumption, and the energy mix supplied to the industrial activities. In terms of environmental impacts, there are **additional dimensions monitored**: air emissions (incl. GHG), and damage to the ecosystem. The following table shows the summary of green performance indicators at EU level and its change from 2010 to 2021.

Table 1: Environmental indicators that capture the environmental impact of the mobility ecosystem, including both production and consumption accounts based on Exiobase data



[83] EEA 2022. Visit 12/10/2022. https://www.eea.europa.eu/data-and-maps/data/external/exiobase
[84] Beylot, A., Secchi, M., Cerutti, A., Merciai, S., Schmidt, J. and Sala, S., 2019. Assessing the environmental impacts of EU consumption at macro-scale. Journal of cleaner production, 216, pp.382-393. https://doi.org/10.1016/j.jclepro.2019.01.134
[85] Remond-Tiedrez, I. and Rueda-Cantuche, J.M. eds., 2019. EU Inter-country Supply, Use and Input-output Tables: Full International and Global Accounts for Research in Input-output Analysis (FIGARO). Luxembourg: Publications Office of the European Union.
[86] EC (2021) REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL. Establishing a carbon border adjustment mechanism. COM(2021) 564 final.

Source: Technopolis Group, 2022, based on Exiobase data

In terms of **greenhouse gas emissions of CO2** (measured in tonnes), the mobility ecosystem is above **the global average** and it is the second industry after agri-food emitting the most C02. Comparing the emissions of the last ten years, we see that although overall emissions have decreased, the reduction from almost 425 to 390 megatonnes is still small. This is only a limited cause for rejoicing, as the reduction is less than ten% and with regard to the global environmental challenges a minor success.

Particulate matter (PM) refers to a mixture of tiny solid and liquid particles suspended in the air. These particles can vary in size, composition, and origin. PM is typically classified based on its size, with the two most common categories being PM10 (particulate matter that is 10 micrometres or less in diameter) and PM2.5 (particulate matter that is 2.5 micrometres or less in diameter). PM2.5 particles are particularly concerning because they are small enough to penetrate deep into the lungs and potentially enter the bloodstream. Sources of particulate matter can include natural events such as dust storms and wildfires, as well as human activities such as vehicle exhaust, industrial processes, and burning of fossil fuels. The composition of PM can vary depending on its source, but may include organic compounds, heavy metals, and other pollutants that can have negative impacts on human health and the environment. Exposure to particulate matter has been linked to a range of health problems, including respiratory and cardiovascular issues, cancer, and premature death. With regard to particulate matter, **there has been no decrease in PM10 and PM25 emissions over the last ten years**. Rather the contrary is the case, particulate emissions from the mobility, transportation, and automotive sector reached a peak in 2021 and is likely to continue to grow.

The mobility, transportation, and automotive sectors rely on a wide range of materials that are typically obtained through **material extraction.** The extraction of these materials can have significant environmental and social impacts, including land use changes, deforestation, water pollution, and greenhouse gas emissions. Although material extraction declined between 2011 and 2015, it **has risen sharply since 2016**, reaching an all-time high in 2020. The material extraction by the mobility ecosystem is **well above the global average**.

In terms of **land use**, the mobility ecosystem is significantly below the global average. The land use has increased slightly in 2020, but has remained at a constant level on average over the last ten years. The mobility, transportation and automotive sector is also a significant **consumer of water** in a number of ways. The production of vehicles, including cars, trucks, and planes, requires significant amounts of water for cooling and other manufacturing processes. For example, the production of a single car can require thousands of gallons of water. Also, the production of fuels used in transportation, such as gasoline and diesel, requires significant amounts of water. For example, the process of refining crude oil into gasoline can use hundreds of gallons of water per barrel. Furthermore, ships and barges used for waterway transportation also require water for a variety of purposes, including cooling, ballast, and sanitation. Although the water consumption of individual vehicles is relatively low, the sheer volume of vehicles on the road means that the transportation sector is a significant consumer of water for vehicle washing and other maintenance activities. Although **water consumption** is below average, it **has increased steadily over the last five years**. This development should be closely monitored.

The mobility, transportation and automotive sector has a significant **impact on biodiversity**, both directly and indirectly. The construction and maintenance of transportation infrastructure, such as roads and railways, can lead **directly** to habitat loss and fragmentation, which can have significant impacts on wildlife populations. The fragmentation of habitats can isolate populations and reduce genetic diversity, making them more vulnerable to environmental changes and other threats. The mobility ecosystem also affects wildlife mortality, either through direct collisions with vehicles or through habitat fragmentation that can lead to animals being forced to cross busy roads or railways. This has an impact on wildlife populations, particularly for species that are already endangered or threatened. There are also **indirect effects**, such as mobility-related air and water pollution can have negative impacts on biodiversity, including changes in plant and animal populations and reduced ecosystem productivity. Polluted water bodies can lead to the decline of fish and other aquatic species, while polluted air can lead to changes in plant communities and reduced pollination of crops. Furthermore, the mobility, transportation and automotive sector is a significant contributor climate change which impacts the biodiversity, including changes in the timing of seasonal events, changes in plant and animal distributions, and increased risk of extinction for vulnerable species. In view of the severe negative consequences of the mobility, transportation and automotive sector on biodiversity, it is worrying that **the loss of biodiversity has increased over the last decade**. Unfortunately, the biodiversity loss due to ecotoxic emissions reached a new peak in 2020.

Appendix A: References

Beylot, A., Secchi, M., Cerutti, A., Merciai, S., Schmidt, J. and Sala, S., (2019). Assessing the environmental impacts of EU consumption at macro-scale. Journal of cleaner production, 216, pp.382-393. https://doi.org/10.1016/j.jclepro.2019.01.134

Deloitte (2023). The future of automotive mobility to 2035 What might mobility providers' role be in tomorrow's value chain? https://www2.deloitte.com/content/dam/Deloitte/global/Documents/gx-deloitte-future-automotive-mobility-study.pdf

European Commission (2020). A New Industrial Strategy for Europe, COM/2020/102 final

European Commission (2021). Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe's recovery, COM(2021) 350 final

European Commission (2021). REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL. Establishing a carbon border adjustment mechanism. COM(2021) 564 final.

European Commission (2021). Annual Single Market Report Brussels, 5.5.2021 SWD (2021) 351 final

European Parliament (2023). CO2 emission standards for new cars and vans 'Fit for 55' package available at : https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/698920/EPRS_BRI(2022)698920_EN.pdf

KPMG (2022). Levelling Up: China's race to an autonomous future.

Remond-Tiedrez, I. and Rueda-Cantuche, J.M. eds., (2019). EU Inter-country Supply, Use and Input-output Tables: Full International and Global Accounts for Research in Input-output Analysis (FIGARO). Luxembourg: Publications Office of the European Union.

Appendix B: Methodological notes

Startup data and venture capital data analysis

Selected fields from Crunchbase and Net Zero Insights:

Table 2: Concordance between NACE and Crunchbase/N0

NACE		Tags
C27	Manufacture of electrical equipment	-
C29	Manufacture of motor vehicles, trailers and semi-trailers	Automotive, Autonomous Vehicles, Electric Vehicles
C30	Manufacture of other transport equipment	
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles	
H49	Land transport and transport via pipelines	Transportation
H50	Water transport	Transportation
H52	Warehousing and support activities for transportation	

Source: Technopolis Group and Kapa Research, 2023

Survey

The table below presents the overview of the sub-sectors included in the sampling frame, with corresponding sections according to the NACE industrial classification.

Table 3: Survey sampling

NACE		Sample size of the survey
C27	Manufacture of electrical equipment	60
C29	Manufacture of motor vehicles, trailers and semi-trailers	115
C30	Manufacture of other transport equipment	65
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles	-
H49	Land transport and transport via pipelines	115
H50	Water transport	-
H52	Warehousing and support activities for transportation	-

Source: Technopolis Group and Kapa Research, 2023

Foreign direct investment data analysis

Table 4: Concordance between NACE and FDI Intelligence data

NACE		FDI
C27	Manufacture of electrical equipment	
C29	Manufacture of motor vehicles, trailers and semi-trailers	
C30	Manufacture of other transport equipment	

G45	Wholesale and retail trade and repair of motor vehicles and motorcycles	
H49	Land transport and transport via pipelines	
H50	Water transport	
H52	Warehousing and support activities for transportation	

Source: Technopolis Group and Kapa Research, 2023

CORDIS data analysis

Codes used:

TED data analysis

Source: Technopolis Group and TED

LinkedIn data analysis

Table 5: Concordance between NACE and LinkedIn

NACE		LinkedIn
C27	Manufacture of electrical equipment	-
C29	Manufacture of motor vehicles, trailers and semi-trailers	Automotive
C30	Manufacture of other transport equipment	Shipbuilding
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles	-
H49	Land transport and transport via pipelines	Transportation, Trucking/Railroad
H50	Water transport	Transportation, Trucking/Railroad
H52	Warehousing and support activities for transportation	Transportation, Trucking/Railroad

Source: Technopolis Group based on LinkedIn

Green skills – keywords used: Cleantech, Sustainability, Sustainable Development, Sustainable Business, Energy Efficiency, Clean Energy Technologies, Renewable Energy, Wind Energy, Biomass, Biomass Conversion, Solar Energy, Solar Power, Urban Forestry, Forest Ecology, Sustainable Communities, Organic Farming, Organic Gardening, Urban Agriculture, Organic Food, Waste Management, Waste Reduction, Recycling, Water Treatment, Water Resource Management, Water Purification, Green Marketing, Green Printing, Environmental Biotechnology, Environmental Science, Environmental Engineering, Environmental Management Systems, Environmental Protection, Wastewater Treatment, Ecology, Circular Economy, Zero Waste, Waste to Energy, Plastics Recycling, E-Waste, Carbon Reduction Strategies, Carbon Footprinting, Carbon Neutral, Energy Retrofits, Biodiversity, Biodiversity Conservation, Nature Conservation, Advanced Materials, Nanomaterials, Biomaterials, Reuse, Separation Process, Sorting, Equipment Repair, Natural Resource Management, Sustainability Reporting, Green Development, Sustainable Cities, Energy Conservation, Energy Management, Environmental Awareness, Environmental Impact Assessment, Environmental Compliance, Leadership in Energy and Environmental Design (LEED), Environmental Policy, Green Technology, Sustainable Design, Sustainable Architecture, Environmental Consulting, Maintenance and Repair, Solar PV, Solar Cells, Wind Turbines, Wind Turbine Design, Carbon Capture, Low Carbon Technologies, Low Carbon, Renewable Fuels, Renewable Energy Systems, Renewable Resources, Integrated Water Resources Management, Natural Resources, Biodiesel, Bioplastics, Waste Treatment, Waste Water Treatment Plants, Electric Vehicles, Hybrid Electric Vehicles, Multi-modal Transportation, Energy Efficiency Consulting, Recycled Water, Adaptive Reuse, Ecodesign, Life Cycle

Assessment, Energy Optimisation, Alternative Fuels, Green Building, Green Infrastructure, Green Purchasing, Biodegradable Products, ISO 14001, EMAS, Environmental Standards

Digital skills – keywords used: data analytics, tourism flow management, online platforms, digital payment, online ticketing, Cybersecurity, Intrusion Detection, Malware Detection, Cloud Security, Cybercrime Investigation, Cyber Threat Intelligence (CTI), Cryptography, DLP, Malware Analysis, IDP; Vulnerability Assessment, Certified Information Security Manager (CISM), Computer Forensics, Cloud Infrastructure, Cloud Services, Google Cloud Platform (GCP), SAP Cloud Platform, SAP HANA, Everything as a Service (XaaS), Software as a Service (SaaS), Platform as a Service (PAAS), Infrastructure as a Service (IaaS), Private Clouds, Hybrid Cloud, Cloud Computing, Edge Computing, High Performance Computing (HPC), Serverless Computing, Robotics, Robot, Robotic Surgery, Human-robot Interaction, Drones, Connected Devices, Internet of Things (IoT), Robotic Process Automation (RPA), Wireless Sensor Networks, Embedded Systems, Cyber-Physical Systems, Smart Cities, Artificial Intelligence (AI), Biometrics, Cognitive Computing, Computer Vision, Deep Learning, Machine Learning, Natural Language Processing (NLP), Natural Language Understanding, Natural Language Generation, Reinforcement Learning, Speech Recognition, Supervised Learning, Unsupervised Learning, Big Data Analytics, Hadoop, Real-time Data, Yarn, Teradata Data Warehouse, Blockchain, Ethereum, Bitcoin, Cryptocurrency, Crypto, Distributed Ledger Technology (DLT), Hyperledger, Augmented Reality (AR), Virtual Reality (VR), Mixed Reality, Computer-Generated Imagery (CGI), Connectivity, M2M, 5G, SD-WAN, Home Automation, Flexible Manufacturing Systems (FMS), Smart Manufacturing, Smart Materials, Quantum Computing, Smart Devices, Intelligent Systems, Big Data, Computer-Aided Design (CAD), Computer Science, MATLAB, C (Programming Language), Python (Programming Language), Digital Strategy, Digital Printing, Digital Marketing, Online Journalism, Revit, Building Information Modeling (BIM), JavaCard, R (Programming Language), Digital Imaging, Digital Media, C++, Collaborative Robotics, Industrial Robotics, Medical Robotics, Mobile Robotics, AutoCAD, Automation, Autodesk 3ds Max, Lumion, Data Analysis, Data Mining, 5G Core, Integrated Security Systems, Cloud Applications, Cloud Computing IaaS, Cryptocurrency Mining, CryptoAPI, Automated Machine Learning (AutoML), Machine Learning Algorithms, Virtual Reality Development, Virtual Data Rooms, Intelligence Systems, Robot Programming, Predictive Analytics, Data Lakes, Blockchain Analysis, Digital Publishing, Enterprise Software, Software Development, SAS (Software), SAP Products, SAP ERP, Online Payment, Online Payment Solutions; Online Travel, Online Marketing, Online Business Management, Online Advertising, Online Gaming, Web Services, Mobile Applications, Mobile Marketing, Java Database Connectivity (JDBC), Data Warehousing, Statistical Data Analysis, Data Modeling, Databases; Electronic Data Capture (EDC), Data Centres, Oracle Database, SAP Solution Architecture Data Entry, Data Management, Data Mapping, Web Applications, GIS Applications, Oracle Applications, Visual Basic for Applications (VBA), Computer Hardware, Computer Maintenance, Computer Network Operations, Computer Networking, Computer Graphics, Online Communications, Social Media Marketing, Digital Direct Marketing, Digital Illustration, Digital Video, Digital Photography, Xero, GPS Applications, GPS Devices, GPS Tracking, GPS Navigation, Microsoft Power Apps, Social Networking Apps, Google Apps Script, Social Media, E-Commerce, Data Intelligence, Online Platforms, Mobile Payments