EUROPEAN
COMMISSION

Brussels, 14.2.2024
SWD(2024) 77 final

COMMISSION STAFF WORKING DOCUMENT

First annual report on key findings from the European Monitor of Industrial Ecosystems (EMI)

Accompanying the document

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions

“The 2024 Annual Single Market and Competitiveness Report"

{COM(2024) 77 final} - {SWD(2024) 78 final}

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Executive Summary

The European Monitor of Industrial Ecosystems (EMI) aims to inform EU policymakers, industry, and Member States about the evolution of the twin transition across individual industrial ecosystems[1], notably by looking at some of its key enablers, and about EU competitiveness in key technologies for the twin transition, also compared to other foreign competitors.

This annex provides a first annual report on EMI findings, first as regards the progress of the twin transition by individual ecosystem, and then as regards the position of EU industry in the global technology race.

On the **progress of the twin transition** by individual ecosystem, the initial results show the following:

- **Uptake of digital and green technologies**

EMI finds that basic digitalisation[2] is still taking place across all industrial ecosystems, with only 69% of Small and Medium-Sized Enterprises (SMEs) having at least basic level of digital intensity in 2022, below the 2030 EU target of 90%[3]. However, there is evidence of a serious commitment by industry to speeding up: e.g., 49% of SMEs reported increasing their investments in digital technologies[4]. This trend is particularly visible in the aerospace and defence and the cultural and creative industries ecosystems. Similarly, 42% of SMEs reported increasing their investments in green technologies, with energy-intensive industries, aerospace and defence, and agrifood leading this.

- **Supply and demand of green and digital skills**

EMI also finds that the availability of digital skills remains limited, especially in some service-based ecosystems like tourism. These low levels of supply contrast with the high demand for such skills, and this gap is particularly high in cultural and creative industries, construction, and tourism. The availability of green skills also remains limited, with no ecosystem having a share of professionals with such skills over 7%. Demand also remains low, with the exception of the Energy-Renewables ecosystem, but is increasing with an average annual growth rate reaching 40% from 2019 to 2022.

- **Private equity and venture capital**

European private equity and venture capital investment in green and digital tech firms have consistently increased since 2016, with significant increases in 2021 and 2022, followed by a drop in the first quarters of 2023. The ecosystems that attracted the most investment in digital firms in 2021 were electronics, retail, and mobility. The latter two were also the ecosystems that captured the most investment in green tech firms, along with agrifood. Despite this, EU businesses are still constrained by the limited availability of private financing, with the US having a much larger number of scale-ups than the EU across all industrial ecosystems, though this gap is narrowing in certain ecosystems, such as mobility, electronics, tourism, and energy-intensive industries.

On the **position of EU industry in the global technology race**, EMI shows the following:

- **Capacity to innovate**

EMI finds that EU innovation is concentrated in climate change technology, but that the EU is giving way in digital competitiveness, with the EU retaining a leading position on transnational patent applications in Renewable Energy

[1] The definition of industrial ecosystems can be found in the 2020 EU Industrial Strategy. The methodology used to define each industrial ecosystem and the NACE rev.2 that each industrial ecosystem encompasses are outlined in the Annual Single Market Report 2021.

[2] The adoption of basic technologies like software services.

[3] Established by the Digital Decade Policy Programme https://ec.europa.eu/commission/presscorner/detail/en/ip_23_4619

[4] These figures are sourced from the results of the business survey that was conducted among SMEs in the context of the EMI project.

Technologies, but lagging behind China and the US in Artificial Intelligence and Big Data. China has caught up with the EU on solar power. On the other hand, the EMI provides further evidence that the EU is still in the lead worldwide in terms of transnational patents in Advanced Manufacturing technologies.

- **Capacity to produce technology-based goods**

EMI shows that the EU produces more than it imports in advanced manufacturing and robotics, renewable energy technologies, advanced materials and nanotechnology, and biotechnology[5]. However, the positive balances between production and imports which were found in the advanced manufacturing and renewable energy technologies have recorded a decrease. Moreover, the analysis shows that the EU produces much less than it imports in Artificial Intelligence and Big Data, both of which are key for industrial competitiveness and to deploy Industry 5.0 solutions.

[5] This data is obtained by matching technology domains with production data from Prodcom,

1. Introduction

The European Monitor of Industrial Ecosystems (EMI)[6] project was launched in 2022 to support EU policymakers, industrial stakeholders, and Member States in assessing the performance of the 14 industrial ecosystems in terms of their green and digital transition. To this effect, based on an established monitoring framework, the project will deliver 14 industrial ecosystem reports on a yearly basis, starting this year, allowing for an assessment of progress over time. This will be complemented annually by 27 Member State reports, several international reports, and one EU report, to provide insights both at country level and vis-à-vis other foreign competitors. In this way, EMI complements other monitoring exercises undertaken by the Commission, such as the Annual Single Market and Competitiveness Report (ASMCR) and the multiple observatories developed by industrial ecosystems. It also helps the monitoring of the implementation of transition pathways[7].

First, EMI has a strong focus on technology generation and uptake as key drivers of competitiveness and of the twin transition. Second, in addition to relying on traditional data sources such as transnational patents and trade, EMI uses novel metrics such as private equity and venture capital based on data from Crunchbase, supply and demand of skills based on data from LinkedIn and Cedefop[8]. In doing so, it is able to address gaps in traditional data sources and deliver findings on a more regular basis.

This is the first annual report and sets out results in five areas: uptake of green and digital technologies, environmental impact, investments and funding, supply and demand of skills, and position of the EU in the global technology race. Although EMI is still in its first year, it presents trends where data has been available for more than 5 years.

2. Uptake of green and digital technologies

2.1. Presence of digital tech startups in the industrial ecosystems

KEY MESSAGES:

- The industrial ecosystems that attract the highest share of digital tech startups are health, mobility, and cultural and creative industries.

- Artificial Intelligence-based tech startups are the most common in health and cultural and creative industries.

- Internet of Things plays the most important role in electronics, healthcare, mobility, and construction.

- Robotics plays the most important role in aerospace and defence and mobility.

- Augmented and virtual reality and blockchain are still considered as niche technologies, but both have been intensifying.

- There is a strong increase in digital tech used for environmental protection across all ecosystems, but most importantly in mobility, electronics, and proximity and social economy.

The uptake of digital technologies can be partially assessed by the presence of digital tech startups in each industrial ecosystem, as such companies can disrupt existing models, push the boundaries of industrial activities and encourage the broader industrial ecosystem to embrace digitalisation. Digital tech firms have become an integral

[6] European Monitor of Industrial Ecosystems (europa.eu)

[7] Transition pathways were announced by the 2021 Industrial Strategy Update. They consist of actionable plans to accelerate the transition in each industrial ecosystem, considering seven building blocks: sustainable competitiveness; regulation and public governance; infrastructure; investments and funding; research, innovation, techniques, and technological solutions; the social dimension; and skills.

[8] A more comprehensive description of the methodology, including a full list of indicators that will be analysed on a yearly basis, is attached at the end of this document.

part of various industries (providing, e.g., online booking and recommendation platforms in tourism or connected vehicles in mobility) and new start-ups are providing a diverse and dynamic nature of solutions shaping industrial futures.

This section identifies which ecosystems have more digital tech startups and which type of technologies (basic or advanced) they adopt. The exercise builds upon the analysis of data from Crunchbase and NetZero Insights.

As found by the analysis of startup data[9], in Europe, a high share of tech startups across all industrial ecosystems offer basic digital solutions such as online platforms (like online marketplaces) and software services or digital applications that are specific to each ecosystem.

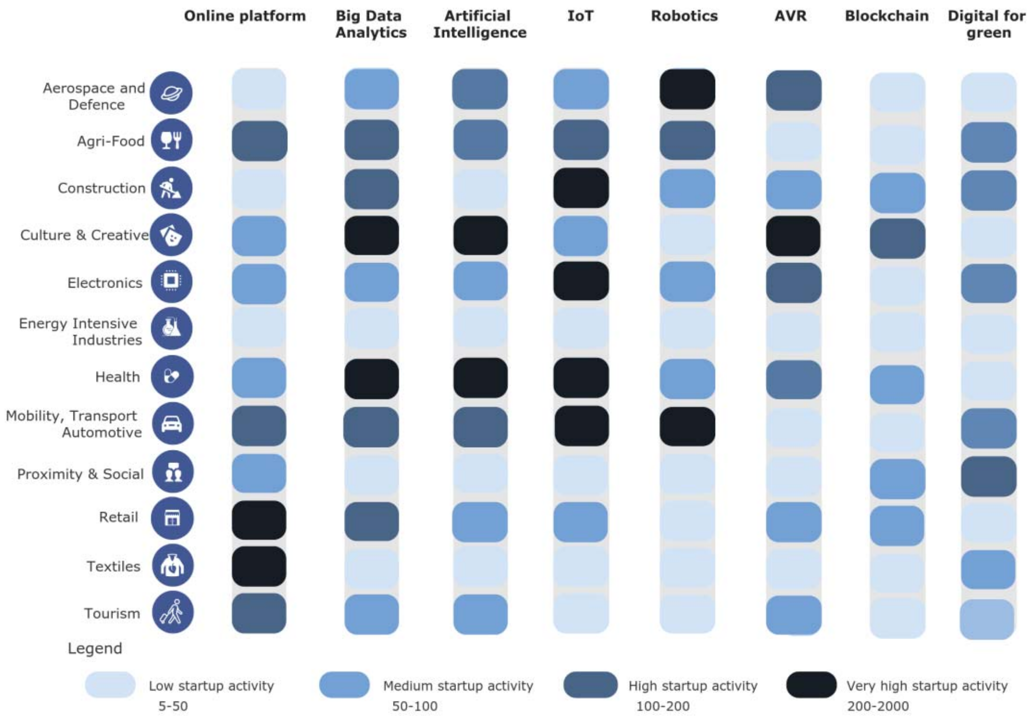
This suggests that the more basic forms of digitalisation such as going online and leveraging digital tools are still taking place. Overall, the analysis identified more startups in these fields compared to advanced digital technologies such as Artificial Intelligence (AI), Big Data, Internet of Things (IoT), robotics, blockchain or Augmented and Virtual Reality (AVR). Figure 1 below provides an overview of the intensity level of technology startups using different digital technologies within industrial ecosystems.

It should be noted that in many cases, more basic forms of digitalisation are more transformative for industrial ecosystems than deep tech. Basic software services provide essential functionality to industrial firms and enable them to manage their operations more effectively. For example, in service ecosystems, emerging cloud-based solutions bridge the gap between the physical and digital world and help these companies to reach out to customers in new ways.

That said, advanced digital technologies provide more innovative functionalities to industrial firms and allow them to be more competitive. As shown by Figure 1 below, some industrial ecosystems have leveraged specific technologies to that end. Such is the case of certain service ecosystems like health and cultural and creative industries, where both AI-based and Big Data-based tech startups are found to be particularly common.

[9] The analysis relies on data from Crunchbase and Net Zero Insights: https://www.crunchbase.com and https://netzeroinsights.com/

Figure 1: Number of digital tech startups (business creation) per EU industrial ecosystem



Source: Technopolis Group, Crunchbase and Net Zero Insights, for the European Monitor of Industrial Ecosystems (EMI) project 2023

On the other hand, in some manufacturing and device-based ecosystems such as electronics, healthcare, mobility, and construction, IoT plays the most important role. Agri-food is following close. Emerging IoT-based products and services include for example, connected elderly care solutions in healthcare, and smart farming and real time monitoring in agri-food.

Robotics have been transforming the aerospace and defence ecosystem, particularly the application of drone technologies and unmanned aerial vehicles. Robotics startups are also active in the mobility ecosystem, contributing to automating car assembly and other production processes.

AVR and blockchain are still considered as niche technologies with fewer specialised startups across all industrial ecosystems. However, they are becoming more popular, especially AVR, which is naturally the more present among start-ups specialised in cultural and creative industries. Blockchain is also gaining ground: for instance, it is used in the cultural and creative industries to manage digital rights.

Digital technologies are increasingly interlinked with clean technologies and environmental solutions, as the growing number of startups that combine both fields demonstrate. Examples include big data analytics and AI-based software that provide solutions for waste management or material optimisation in specific industries.

2.2. Adoption of green and digital technologies by SMEs across industrial ecosystems

KEY MESSAGES:

- On average, 42% of SMEs surveyed reported increasing their investments in the green transition, and 49% claimed to have increased their investments in digital technologies;

- The lowest levels of uptake of digital technologies are in the proximity and social economy ecosystem, whereas the highest are in aerospace and defence;

- On average, 20% of surveyed SMEs reported investing into energy-saving technologies, with agri-food, tourism, and textiles accounting for most of the investments;

- On average, 25% of European SMEs have adopted cloud technologies, predominantly in aerospace and defence and in textiles;

- The adoption rate of AI among European large enterprises was 28%, while for SMEs, it was 9%, with the highest rates being recorded in the health and aerospace and defence ecosystems.

The technological uptake of green and digital solutions by SMEs offers a snapshot of how the European economy is transforming at large, beyond big companies that have more resources to dedicate to this process. This section details the results of a dedicated survey among SMEs and explores their level of investments and adoption of green and digital technologies[10].

Investments and adoption of Green Technologies by SMEs

According to the business survey conducted under EMI[11], 42% of SMEs on average across all industrial ecosystems have increased their investments aimed at the green transition and plan to continue investing. In general, service ecosystems[12] have a more diverse green technology uptake than manufacturing ecosystems. The latter mainly focus on energy saving and recycled materials. Technologies related to carbon capture or the use of green hydrogen have been taken up the least.

In terms of the specific green technologies[13] that these companies have invested in, on average 20% of SMEs across industrial ecosystems invested into **energy-saving technologies**. Similarly, the use of recycled materials has been an emerging practice, with an adoption rate of 21% among SMEs, particularly by manufacturing ecosystems such as textiles and agri-food (see Table 1 below).

However, there is a lower take up - 11% - of **circular business models**. The most popular business practices and business models are the product-as-a-service and leasing models, where customers obtain temporary access to a product via leasing or pay-per-use schemes. The ecosystems using this the most are health with 22.3%, aerospace and defence with 14.3%, and construction with 13.4%. However, remanufacturing, which increases a product's lifetime and allows the revaluation of products, is still very limited, which may be due to the related complexities, software restrictions, and high costs.

[10] It should be noted that industrial ecosystems are different in terms of structure and nature – therefore, when making a direct comparison of the survey results, one should put the results into context. The focus of this survey has been SMEs as they represent 99,9% of European businesses.

[11] The in-house business survey collected data about the level of change towards the green and digital transition of European SMEs across twelve industrial ecosystems and gathered opinions about the related investments and expected future developments. The survey was based on using Computer Assisted Telephone Interviewing (CATI). The final sample included 8 987 companies with input from high-level decision-makers.

[12] The following ecosystems are considered services ecosystems: CCI, tourism, proximity and social economy, health, and retail.

[13] The complete list of advanced technologies (green, digital, and key enabling technologies) can be found in the annex.

There is a mixed uptake of **clean production technologies**, including waste and water reduction technologies. Ecosystems such as tourism, health, and agri-food show a high degree of clean production technologies with 23.3%, 24.3% and 28.6% respectively, whereas electronics and cultural and creative industries show lower levels.

Figure 2: Share of SMEs that have reported increasing their expenditure in green technologies per industrial ecosystem in the EU27 over the past 5 years

	Agri-Food	Textiles	Energy Intensive Industries	Mobility, Transport Automotive	Aerospace and Defence	Electronics	Construction	Tourism	Health	Culture & Creative	Retail	Proximity Social
Energy-Saving Technologies	33,6%	27,8%	19,4%	20,1%	26,1%	14,0%	22,6%	28,6%	15,1%	18,8%	14,0%	10,2%
Recycled Materials	32,3%	32,0%	20,4%	19,0%	20,1%	12,1%	22,2%	30,6%	23,9%	20,4%	12,1%	8,4%
Recycling Tech	31,7%	24,3%	20,2%	18,9%	15,9%	11,0%	20,3%	21,5%	23,9%	17,0%	10,7%	9,4%
Renewable Energy	27,9%	18,0%	16,9%	15,9%	11,7%	12,5%	19,8%	23,9%	23,7%	14,1%	9,9%	17,8%
Clean production/ water/waste	28,6%	24,3%	17,6%	13,4%	11,5%	8,1%	15,0%	23,2%	25,2%	11,3%	4,9%	2,7%
Advanced Materials	27,5%	23,3%	16,5%	20,3%	8,8%	5,9%	10,2%	21,4%	23,0%	9,3%	3,1%	3,2%
Carbon capture	11,8%	6,0%	9,8%	11,8%	5,7%	5,9%	8,3%	10,8%	16,6%	3,9%	0,8%	3,2%
Hydrogen	12,4%	1,3%	8,7%	6,1%	4,8%	2,2%	2,8%	5,4%	1,2%	0,9%	0,8%	3,2%

Manufacturing-oriented industrial ecosystems where some industries are driven by strong regulatory actions (Agri-Food to Construction)

Services-oriented industrial ecosystems where some are driven by societal changes (Tourism to Proximity Social)

Source: Technopolis Group and KAPA Research, *for the European Monitor of Industrial Ecosystems (EMI) project 2023*

<u>Investments and adoption of Digital Technologies by SMEs</u>

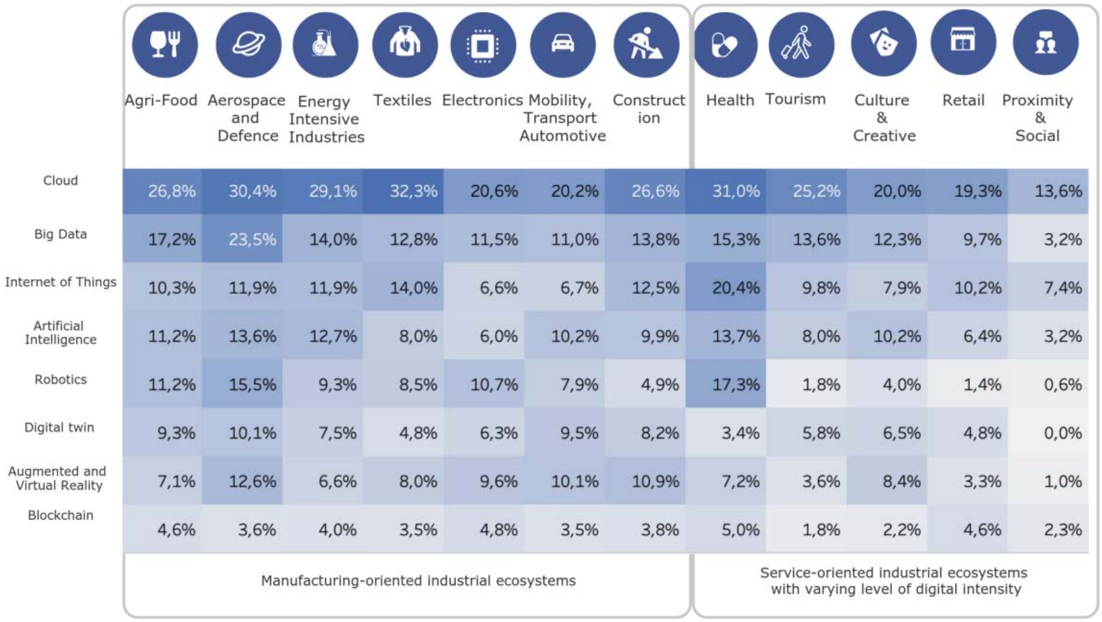
On average, 49% of surveyed SMEs across all industrial ecosystems have increased their investments in digital technologies. However, the share varies across the ecosystems with higher levels in aerospace and defence (68.8%), and cultural and creative industries (65.3%) and mush lower levels in textiles, retail, and electronics.

Figure 3: Share of SMEs that reported increasing their expenditure in digital technologies per industrial ecosystem in the EU27 over the past five years

Source: Technopolis Group and KAPA Research, *for the European Monitor of Industrial Ecosystems (EMI) project* 2023

As regards the adoption of **advanced digital technologies** more specifically, Figure 4 indicates the share of SMEs in each industrial ecosystem that have adopted each technology. The results show that cloud technologies have overall the most relevance for SMEs, corroborating Eurostat data[14]. Similarly, the data suggests that adoption is increasing, but use is mainly limited to communication systems and data storage. Textiles (32.3%), health (31.0%) and aerospace and defences (30.4%) are the ecosystems that are using the most cloud computing technologies.

Figure 4: Share of SMEs that have adopted advanced digital technologies per industrial ecosystem in the EU27



	Agri-Food	Aerospace and Defence	Energy Intensive Industries	Textiles	Electronics	Mobility, Transport Automotive	Construction	Health	Tourism	Culture & Creative	Retail	Proximity & Social
Cloud	26,8%	30,4%	29,1%	32,3%	20,6%	20,2%	26,6%	31,0%	25,2%	20,0%	19,3%	13,6%
Big Data	17,2%	23,5%	14,0%	12,8%	11,5%	11,0%	13,8%	15,3%	13,6%	12,3%	9,7%	3,2%
Internet of Things	10,3%	11,9%	11,9%	14,0%	6,6%	6,7%	12,5%	20,4%	9,8%	7,9%	10,2%	7,4%
Artificial Intelligence	11,2%	13,6%	12,7%	8,0%	6,0%	10,2%	9,9%	13,7%	8,0%	10,2%	6,4%	3,2%
Robotics	11,2%	15,5%	9,3%	8,5%	10,7%	7,9%	4,9%	17,3%	1,8%	4,0%	1,4%	0,6%
Digital twin	9,3%	10,1%	7,5%	4,8%	6,3%	9,5%	8,2%	3,4%	5,8%	6,5%	4,8%	0,0%
Augmented and Virtual Reality	7,1%	12,6%	6,6%	8,0%	9,6%	10,1%	10,9%	7,2%	3,6%	8,4%	3,3%	1,0%
Blockchain	4,6%	3,6%	4,0%	3,5%	4,8%	3,5%	3,8%	5,0%	1,8%	2,2%	4,6%	2,3%

Source: Technopolis Group and KAPA Research, *for the European Monitor of Industrial Ecosystems (EMI) project* 2023

New streams of **big data** (such as production or customer data) also seem to have high relevance for SMEs, in particular those in the aerospace and defence ecosystem and to a lesser extent those in the health and agri-food ecosystems.

AI has been taken up by 9% of SMEs corroborating Eurostat data (and as highlighted in the First SDD Report of the European Commission using DESI[15]. which also shows that the AI adoption rate among European large enterprises was 30%. Industrial ecosystems with the highest uptake include aerospace and defence and health. The most relevant application of AI concerns the optimisation and automation of production (or other business) processes.

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14 https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Cloud_computing_-_statistics_on_the_use_by_enterprises#:~:text=41%20%25%20of%20EU%20enterprises%20used,mail%20and%20storage%20of%20files.&text=Compared%20with%202020%2C%20the%20use,the%20retail%20trade%20in%202021.

15 State of the Digital Decade Report (September 2023), https://digital-strategy.ec.europa.eu/en/library/2023-report-state-digital-decade. Source: Enterprises using any AI technology as % enterprises (Eurostat - European Union survey on ICT usage and e-commerce in enterprises (indicator code: ISOC_EB_AI [E_AI_TANY], 2023; https://ec.europa.eu/eurostat/databrowser/view/isoc_eb_ai__custom_9268325/default/table?lang=en – EU DESI 2023).

Blockchain technologies[16] have the lowest adoption rate across industrial ecosystems with an average uptake of 3%. They are mostly used in the health and agri-food ecosystems, where they can be leveraged to ensure food safety and enhance transparency throughout their supply chains.

2.3. Environmental impact of industrial ecosystems

KEY MESSAGES:

- Total net greenhouse gas emissions have fallen by 0.3% over the period from 2010-2021.

- Material extraction in most industrial ecosystems has fallen slightly, except for agri-food and energy intensive industries, which have seen an increase over the past decade.

- Industrial ecosystems increased their negative impact to the environmental ecosystem (i.g. loss of biodiversity) with a 2.3% compound annual growth rate from 2010 to 2021.

- Land use and the water consumption have also been steadily growing, each at an estimated compound annual growth rate of around 1% in the most industrial ecosystems from 2010 to 2021.

- Environmental impacts per value added have been decreasing in some industrial ecosystems such as construction.

This section assesses the environmental impact of the 14 industrial ecosystems by adapting the European Environmental Agency's environmental indicators typology[17] in six areas of analysis notably: GHG emissions, particulate matter emissions (air pollution), levels of material extraction, land use, blue water consumption, and damage to the environmental ecosystem. Such an analysis of industrial ecosystems offers a snapshot of the main factors that cause pressure on the environment as a result of industrial development. The assessment of this impact is measured by Exiobase data.

According to Exiobase data[18], and as shown by Figure 5, **material extraction** across industrial ecosystems during the last 10 years declined, albeit slightly. This reduction may be due to the reduction in material extraction by the construction ecosystem (-0.7%), which is the major cause of material extraction. However, the agri-food and the energy intensive industries saw an increase in material extraction over the last decade, (0.5% and 1.4% respectively).

Similarly, the total net **greenhouse gas emissions** from the EU industrial ecosystems fell by 0.3%, over the period of 2010-2021 with the exception of the agri-food (0.1%) and energy-intensive industries (1.1%) ecosystems.

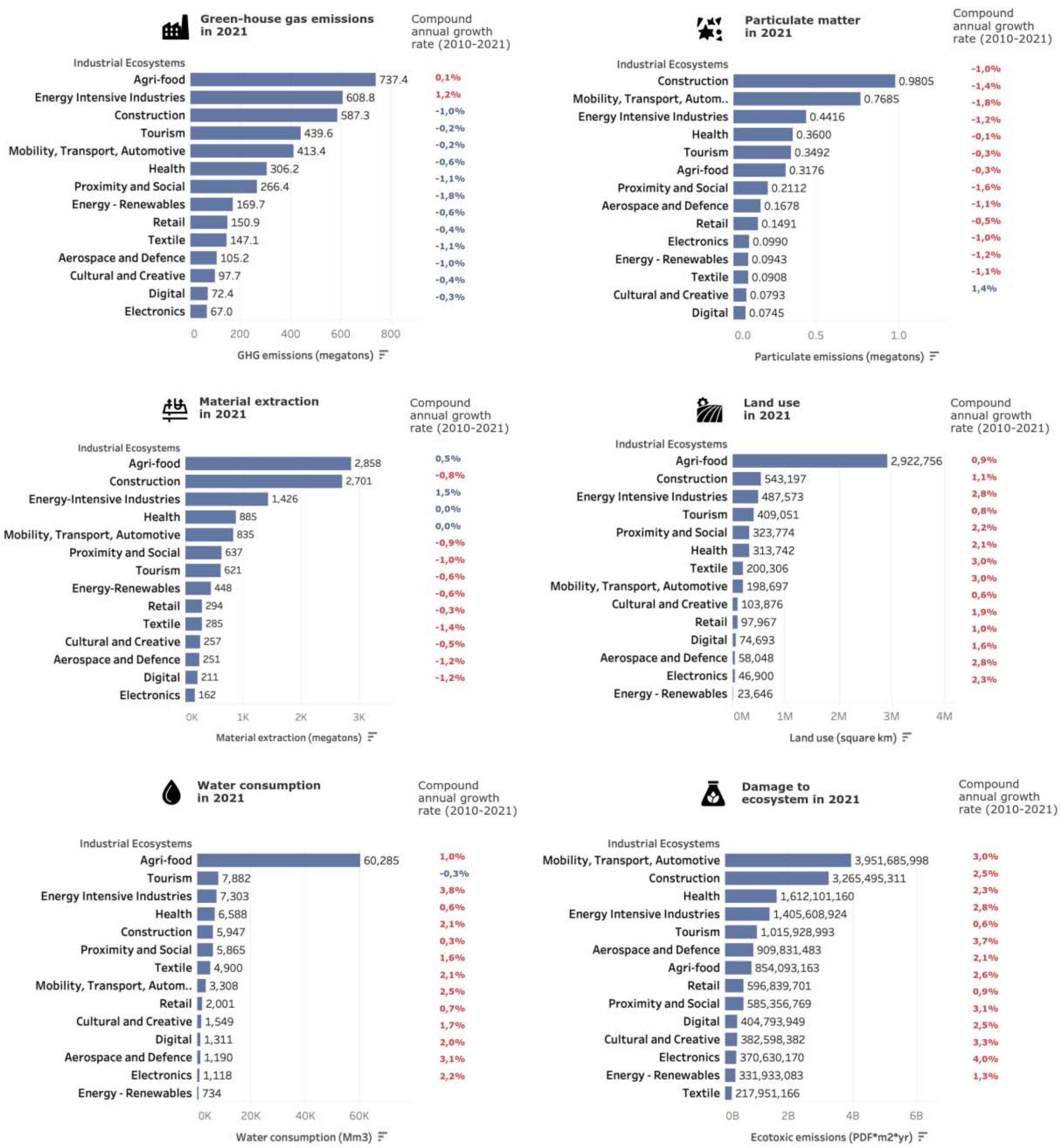
On average, all industrial ecosystems increased their level of damage to the environmental ecosystem (i.e., damage to biodiversity) by 2.3% yearly (over the period from 2010-2021). Land use and blue water consumption in most industrial ecosystems have also been growing steadily. The estimated compound annual growth rate in land use was 1.2%, and 1.1% in blue water consumption over the period from 2010 to 2021. The ecosystems that require more land use and blue water consumption are agri-food and tourism.

[16] Blockchain technologies are a particular type of DLT that employs cryptographic techniques to record and synchronize data in 'chains of blocks'. All types of Blockchain are DLTs but not all DLTs are Blockchains. Blockchain entails three technologies, the blockchain itself, distributed ledger technologies, and smart contracts. Together they represent a fault-tolerant systems synchronising data through consensus mechanisms, able to verify - peer to peer - the correctness of such data through hash functions and values without central authorities and executed upon some basic premises and protocols specified in digital form.

[17] Indicators (europa.eu)

[18] Exiobase is a global, detailed Multi-Regional Environmentally Extended Supply-Use Table (MR-SUT) and Input-Output Table (MR-IOT). It was developed by harmonizing and detailing supply-use tables for a large number of countries, estimating emissions and resource extractions by industry. Exiobase is a legitimate source of information referred by the European Environmental Agency, JRC and Eurostat and the European Commission to propose the regulation on carbon border adjustment mechanisms.

Figure 5: Environmental impacts of the EU industrial ecosystems in 2021 and over time



Source: Technopolis Group based on Exiobase, 2023, for the European Monitor of Industrial Ecosystems (EMI) project 2023

At a more granular level, within each industrial ecosystem, there are certain industries that drive the environmental impact.

The **agrifood** ecosystem is the one that naturally requires more land use and blue water consumption, which have seen (for this ecosystem) a compound annual growth rate of 0.8% and 1% respectively from 2010 to 2021. Most environmental impacts of the ecosystem are driven by the manufacturing of food products. As regards blue water consumption more specifically, crop and animal production, hunting and related services are the key drivers.

In **energy-intensive industries,** the manufacturing of rubber and plastic products were the major contributors to material extraction and blue water consumption. Overall, the energy-intensive industries ecosystem increased its material usage from 1 225 megatons in 2010 to 1 425 megatons in 2021. These results align with other studies finding that in 2015, seven EU countries that manufacture rubber and plastic were major contributors to environmental damage per unit of production value[19]. On the other hand, the manufacturing of basic metals is the key driver of the damage to the environmental ecosystem, whereas the manufacturing of wood and wood products and cork is the key driver of land use in this industrial ecosystem.

2.4. Private investments and funding per ecosystem

KEY MESSAGES:

- European private equity and venture capital investment in green tech and digital tech firms [20]increased significantly in 2021 and 2022, followed by a drop in the first quarters of 2023.
- In 2021, the ecosystems that attracted the most venture capital investments and private equity for digital tech firms were retail, electronics, and mobility, whereas for green tech companies, it was mobility, agrifood, and retail.
- The industrial ecosystem that attracts the least amount of venture capital is textiles.
- Since 2018, the EU has had an increasingly negative FDI balance in the renewables ecosystem.
- The electronics ecosystem is one of the few industrial ecosystems that has maintained a positive net FDI balance since 2017.

Private funding plays a crucial role in driving competitiveness and transformation within industrial ecosystems, enabling advancements in technology and infrastructure and helping industries adapt to digital trends and address pressing environmental challenges.

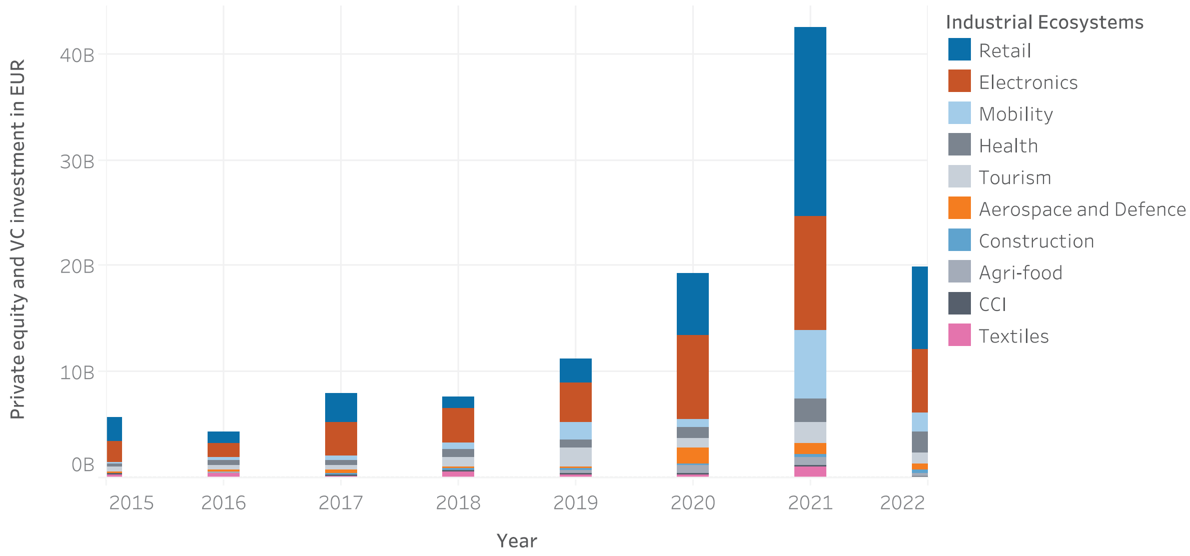
This section looks at how private equity, venture capital, and foreign direct investments are supporting green and digital firms. Investment data has been captured from Crunchbase[21], NetZero Insights[22] and Trendeo[23] and considers the 4 investment stages (seed, early investments, late investments, and exit).

European private equity and venture capital investment (VC) for green and digital investments increased significantly in 2021 and 2022, followed by a drop in the first quarters of 2023. This can be seen in the venture capital investment analysis of industrial ecosystems (see Figure 6) and has been highlighted in several recent reports[24] [25].

Private equity and venture capital investments into **digital tech firms** embedded in different ecosystems have been continuously increasing. The ecosystems that attracted the most investment in digital transformation in 2021 include retail (42 billion euros), electronics (25 billion euros), and mobility (16 billion euros).

[19] The seven EU countries included Austria, Belgium, Germany, Denmark, France, Netherlands, and United Kingdom. See Brink, C., Drissen, E., Vollebergh, H., & Wilting, H. (2020). Accounting for Environmental Damage by Material Production and Use: A Comparison of Seven Western European Countries. (PBL Publication; Vol. 3512). Planbureau voor de Leefomgeving.
[20] Digital or green/environmentally sustainable companies have been defined as those that specifically serve or are part of the industrial ecosystem in focus and at the same time develop or deploy any of the green or digital technologies defined under the EMI project.
[21] https://news.crunchbase.com/venture/europe-vc-funding-drops-q1-2023/
[22] The Net0 Platform enables users to filter organisations based on Technology, EU Taxonomy, Value Chain, Business model, funding data, stage, investors, etc. The data provided by Net) platform allow to get **insights** on climate tech investments.
[23] Trendeo: https://trendeo.net
[24] Private Equity at Work – job creation and employment across Europe | Invest Europe: https//www.investeurope.eu/research/private-equity-at-work/
[25] European VC funding drops 66% as seed takes a hit, US investors pull back: http://news.crunchbase.com/venture/europe-vc-funding-drops-q1-2023/

Figure 6: Private equity and venture capital funding raised in digital transition-related technologies per industrial ecosystem

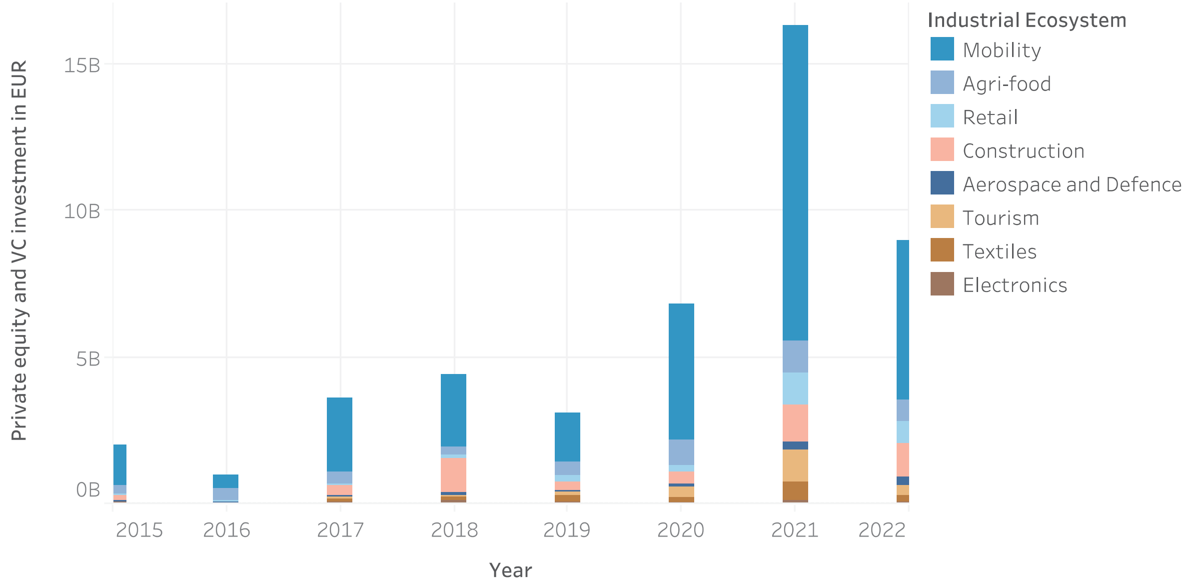


Source: Technopolis Group based on Crunchbase and Net Zero Insights, for the European Monitor of Industrial Ecosystems (EMI) project 2023

As regards **green tech companies**, private equity and venture capital investment shows a similar pattern with investments increasing since 2016. Ecosystems with the highest private equity and VC funding into green technology-related firms include mobility, given the link to electric vehicles and shared mobility services. Agri-food follows suit, with investments into precision agriculture and other sustainability startups. Retail has also attracted investments, captured especially for second-hand retail and sharing economy[26].

[26] The sharing economy is an economic model defined as a peer-to-peer(P2P) based activity of acquiring, providing, or sharing access to goods and services that is often facilitated by a community-based online platform.

Figure 7: Private equity and venture capital funding raised in green transition related technologies per industrial ecosystem



Source: Technopolis Group based on Crunchbase and Net Zero Insights, *for the European Monitor of Industrial Ecosystems (EMI) project 2023*

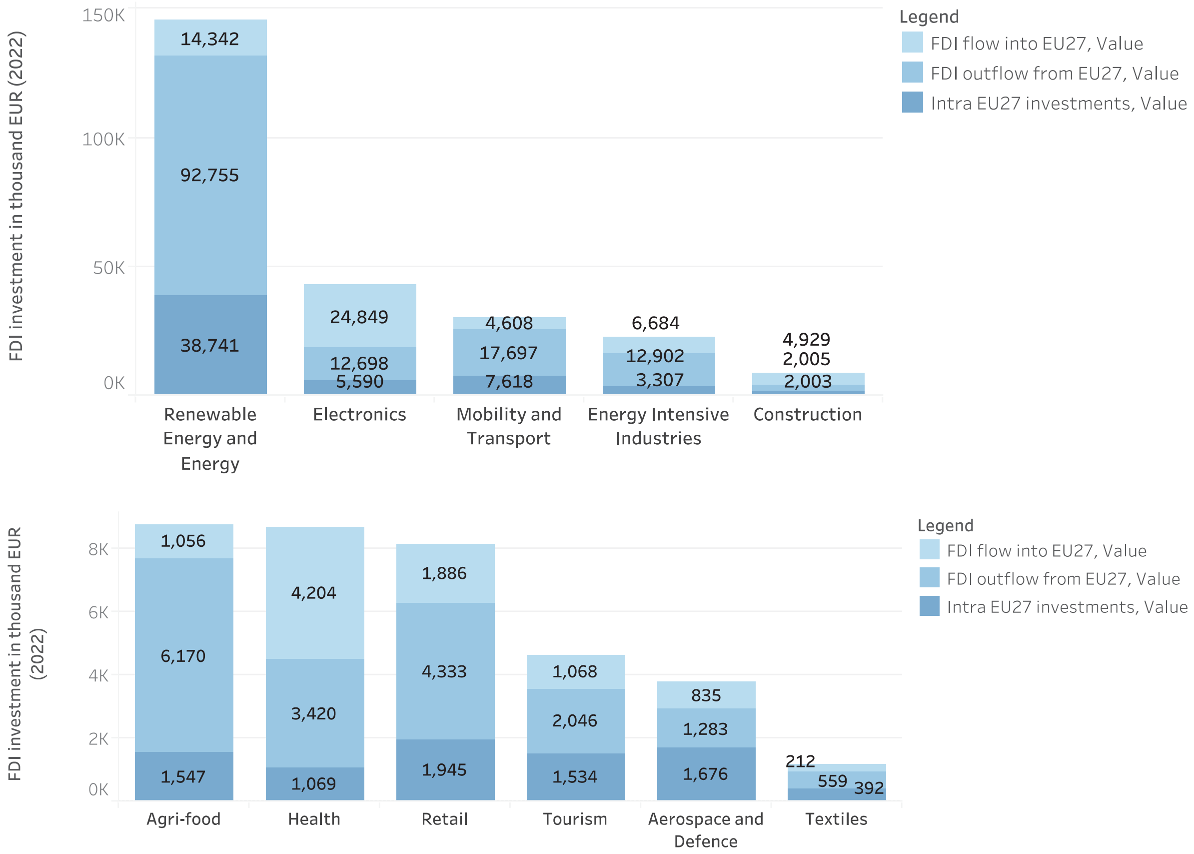
Generally speaking, **foreign direct investments** (FDI) are often regarded as a channel to foster technology and knowledge diffusion, as well as global value chain integration. Within the EU more specifically, intra-EU FDI also has an extremely relevant role, as it enables the creation of new value chains and industrial capacities. Nonetheless, it should be noted that FDI can also mean creation of dependencies in industrial value chains.

With this in mind, trends in FDI have been analysed with data from foreign direct investments intelligence[27] that tracks cross-border greenfield investment both intra EU, extra EU and globally, covering each industrial ecosystem.

Figure 8 displays the industrial ecosystems that witnessed the largest FDI flows, including renewable energy, electronics, and mobility, transport and automotive.

[27] FDI Intelligence tracks cross-border greenfield investment covering all sectors and countries worldwide, it provides real-time monitoring of investment projects, capital investment and job creation with powerful tools to track and profile companies investing overseas. FDI Intelligence only track real projects that will create new jobs, therefore they do not cover merges and acquisitions.

Figure 8: Foreign direct investments per industrial ecosystem



Source: Technopolis Group calculations based on foreign direct investments insights Intelligence for the European Monitor of Industrial Ecosystems (EMI) project 2023

In the field of **renewable energy/energy**, the EU's net FDI balance has been increasingly negative, despite the increasing number of greenfield investments since 2012. This is due to a rise in FDI outflows from European countries to non-EU destinations since 2018, which amounted to a total of EUR 92 billion in 2022, compared to EUR 53 billion of FDI inflows into the EU. The primary recipients of EU27 FDI outflows during the period of 2018-2022 were the UK and the US, which received EUR 33 billion (33%) and EUR 88 billion (13%) respectively. On the other hand, intra-EU investments for the renewable energy sector have been increasing for the considered period, reaching a total of €EUR 38 billion in 2022, which represents a compound annual growth rate of 18.7% from 2015 to 2022.

The **electronics** ecosystem has maintained a positive net FDI balance since 2017, with both intra-EU FDI and inward investments increasing in recent years. Non-EU FDI inflows into the EU account for the largest volume of investments, reaching a peak of EUR 27.8 bn and experiencing an average growth rate of 83% since 2016. The United States was the top investor during this period, having invested EUR 44 bn (62% of total FDI), followed by China (22%). Looking at the European recipients, Germany ranks first, having received EUR 27.6 bn during the period 2016-2022, followed by Ireland (EUR 17.6 bn), Hungary (EUR 12 bn), and Italy (EUR 6.4 bn).

In the **mobility, transport and automotive ecosystem**, the net FDI balance has been negative between 2010 and 2022. However, after 2018, FDI outflows from the EU in the ecosystem sharply decreased, resulting in a 50%

decrease in this deficit in 2022 compared to 2010. Germany is the largest European investor, both outside and intra-EU, having invested a total of EUR 84 bn between 2015 and 2022. Out of this amount, 24.4% of the investments were directed to China.

In the **energy-intensive industries ecosystem**, the EU also has a negative net FDI balance, amounting to EUR 2.9 billion in 2022. However, this negative net FDI has decreased in volume due to a decrease in the outflows of investments by 53% in 2022 compared to 2010 data. Moreover, intra-EU27 investment and FDI flows into the EU27 increased by 32% and by 63% respectively since 2015.

On the other hand, the EU's net FDI balance in **agri-food** has been increasingly negative since 2018. This can be attributed to an increasing outward investment flow from the EU, accompanied by a declining FDI inflow since 2017. The top recipients of EU FDI during the period between 2015 and 2022 were the United States, United Kingdom, Russia, and China. Among the EU, the Netherlands is the largest investor outside the EU (followed closely by Germany), having invested a total of EUR 11.84 billion between 2015 and 2022.

The **top foreign investors** into the EU economy during the considered period over the period from 2015 to 2022 were the United States and United Kingdom, which invested a total of EUR 29.5 billion and EUR 15 billion respectively**.** The largest recipients in the EU during the same period were Poland, Spain, and France, accounting for 27%, 15%, and 14% of the total FDI flowing into the EU.

2.5. Supply and demand of skills to support the twin transition

KEY MESSAGES:

- The highest share of professionals indicating at least one green transition related skill[28] are in construction, energy-intensive industries and aerospace and defence.

- Demand for green skills has been growing from 2019 to 2022, particularly in energy-renewables, which has seen an average annual growth rate of 40%.

- The supply of moderate digital skills remains particularly limited in healthcare, agrifood, tourism, and textiles.

- Cultural and creative industries, aerospace and defence, electronics, and construction are the ecosystems with the highest levels of supply of moderate digital skills.

- The industrial ecosystems that recorded the highest demand of moderate to advanced digital skills were cultural and creative industries, construction, and energy

Upskilling and reskilling is one cornerstone of the EU industrial policy. This section showcases the supply and demand of green and digital skills in each industrial ecosystem by using LinkedIn and CEDEFOP data. The use of these sources is a way of overcoming the lack of data sources where skills can be monitored. LinkedIn data is particularly informative, as it allows for the consideration of not only formal skills recognised by certifications or diplomas but also skills acquired on the job[29].

[28] EMPLOYMENT AND SOCIAL AFFAIRS (EXTERNAL COM) - New taxonomy of skills for the green transition (europa.eu). Examples of green transition skills are: sustainable design or passive house building skills in construction,. agronomy in agri-food.
[29] It is important to highlight the information provided by the LinkeIn users in their profiles is based on their self-assessment/self-evaluation.

Supply and demand of green skills

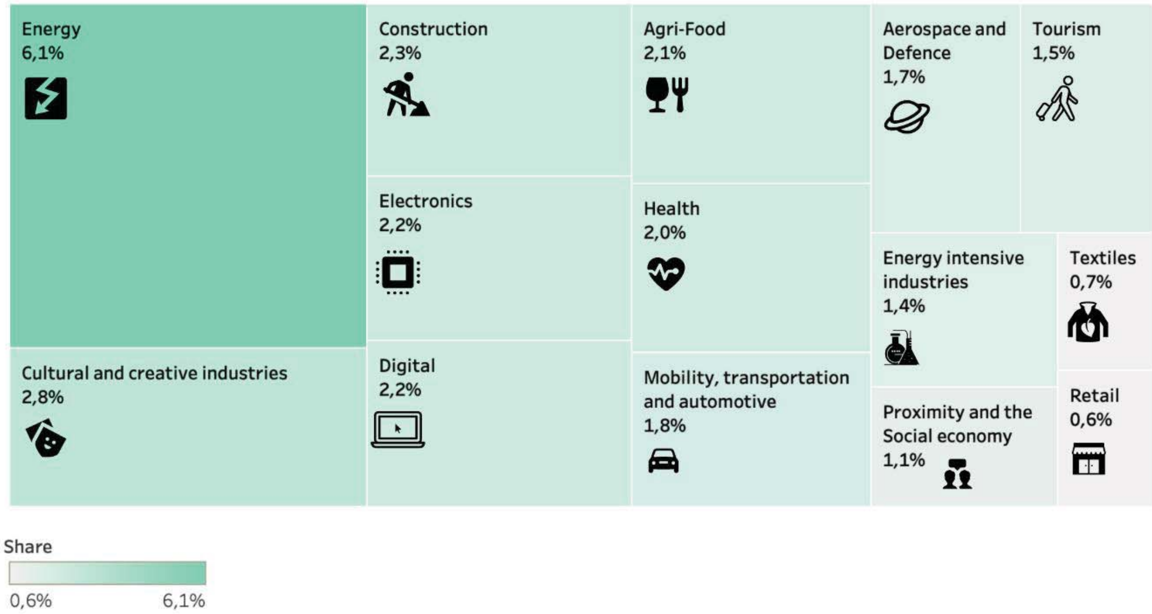
LinkedIn data show that construction, energy-intensive industries and aerospace and defence are the industrial ecosystems with the highest share of professionals indicating at least one green transition related skill[30] on their LinkedIn profile.

Nevertheless, these differences should be treated with caution. First, some industrial ecosystems have strong environmental standards, so it is natural to find more professionals with the related skills. Second, although there is a need to hire environmental specialists, this green expertise is often outsourced to consulting companies. Third, some traditional functions have become greener without this change having been made explicit.

In terms of **demand** for green skills, there is a growing interest for the integration of more sustainable processes, confirmed by the data on green job advertisements extracted from Cedefop which shows that in the period 2019 – 2022[31], the demand for green skills in job advertisements grew consistently throughout most industrial ecosystems. More specifically, the share of job advertisements requiring green skills grew at an average annual growth ranging from 2% (textiles) to 40% (energy-renewables).

Nevertheless, the analysis shows that the shares of job advertisements with the explicit requirement of a green transition-related skill are still low (below 3%) across most industrial ecosystems, except for the energy ecosystem.

Figure 9: Share of online job advertisements requiring green skills



Source: Technopolis Group based on Cedefop Skillovate data, for the European Monitor of Industrial Ecosystems (EMI) project 2023

Supply and demand of digital skills

Increasing digital skills in the population is one of the biggest challenges of the EU, cutting across all objectives and targets[32]. LinkedIn data shows that the industrial ecosystems with the highest supply of moderate digital skills

[30] EMPLOYMENT AND SOCIAL AFFAIRS (EXTERNAL COM) - New taxonomy of skills for the green transition (europa.eu)

[31] Outcome of assimilation of information through learning. Knowledge is the body of facts, principles, theories, and practices related to a field of study or work (Cedefop Glossary, 2023)

[32] 2023 Report on the state of the Digital Decade | Shaping Europe's digital future (europa.eu), P.25

(about 30%) are those that use advanced software and programming: cultural and creative industries and aerospace and defence. In industrial ecosystems that are 'digital by definition', such as the digital and the electronic industries, there is also a considerable share of professionals with digital skills (e.g., in electronics, it is 27%).

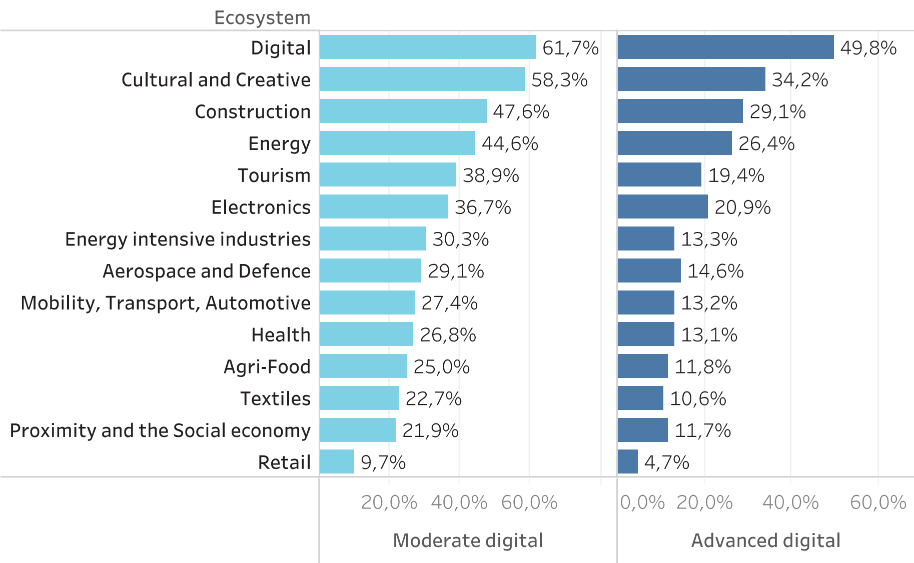
Nevertheless, overall, the **supply** of digital skills remains limited, in particular in services-related ecosystems. For example, in the tourism industry, only 5% of the workforce have advanced digital skills such as computer programming and database management. However, the data on the demand of digital skills in the next section indicates that the tourism industry is eager to attract more digital talents as 17% of the advertisements require digital skills.

In the health ecosystem, the uptake of digital skills in the workforce seems slower than in other ecosystems. LinkedIn data indicates that only 13.7% of health professionals highlighted moderate digital skills on their profiles.

As regards advanced digital skills (e.g. AI, robotics or IoT), these are found mostly in aerospace and defence and electronics. The lowest share of professionals with advanced digital skills were found in tourism, textiles and agri-food.

In terms of **demand** for digital skills, Cedefop data indicates that there are large variations among industrial ecosystems. Cultural and creative industries (CCI) are embracing the digital transition, as more than half of job advertisements (58%) require at least moderate digital skills. However, in the retail industry, digital skills are not in high demand, as only 4% of job advertisements required them. According to the Retail Pact for Skills, digital skills are however highly needed in the retail sector[33], especially advanced IT skills for e-commerce and knowledge of data analytics.

Figure 10: Share of online job advertisements requiring moderate and advanced digital skills in the EU27



Source: Technopolis Group analysis based on Cedefop Skillovate data, for the European Monitor of Industrial Ecosystems (EMI) project 2023

[33] Pact for Skills – Skills Partnership for the Retail Ecosystem

At a more granular level, the skills which are driving the demand are business ICT systems, computer programming, databases, and performing data analysis. These skills are among the top 10 skills required in job advertisements for most industrial ecosystems.

Many of these skills are connected with online marketing techniques, for which there is a clear demand, especially among service-based ecosystems[34]. These skills include proficiency in digital marketing strategies, social media marketing, advanced web techniques such as web analytics and programming, as well as online analytics processing. The industrial ecosystems where this is especially relevant are tourism, textiles, retail, health, creative and cultural industries, proximity and social economy, and agri-food.

That said, AI is also gaining importance in terms of skills demand – as highlighted by the job titles 'AI Engineer' and 'Head of AI' ranking as the fastest growing digital titles. These findings indicate that there an increasing interest for integrating AI into industrial processes, especially in the digital and the aerospace and defence ecosystems. However, despite this strong growth, there is still a reported lack of supply of AI specialists[35].

3. Position of EU industry in the global technology race

3.1. The EU's innovation capacity in green and digital technologies

KEY MESSAGES:

- Levels of innovation for the EU and the US have remained stable in absolute terms, but both have lost some ground in relative terms to China.

- Although the EU is still ahead in terms of green technologies, its innovation capacity in digital technologies is relatively limited compared to the China and the US, especially in AI and Big Data.

-The EU displays a relatively strong position globally in terms of patent data in aerospace & defence, agri-food, construction, renewable energies, mobility, transport and automotive and textiles.

In this section, we examine data provided by the EPO's Worldwide Patent Statistical Database[36] pertaining to transnational patents per individual technology and per industrial ecosystem, comparing the EU to the US and China.

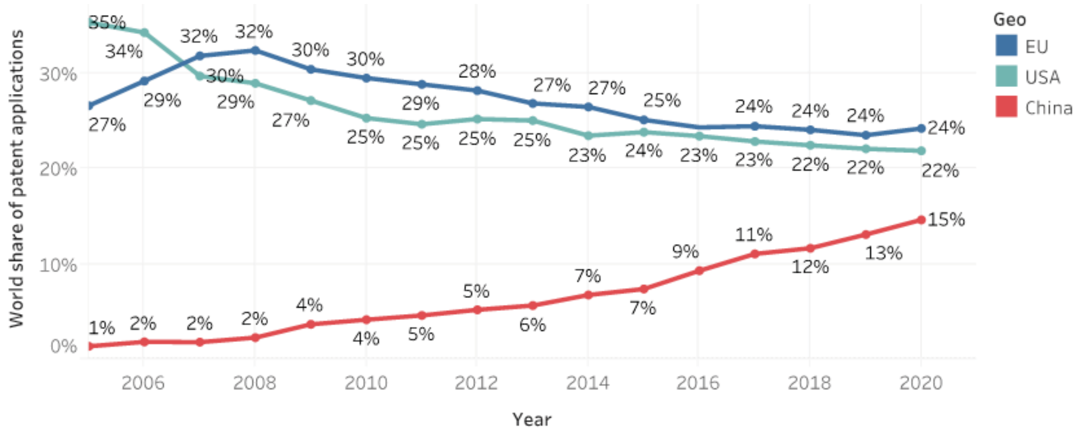
Comparing the EU, China, and the US on transnational patents indicate that the EU's world share of transnational patents has been similar to that of the US, and in absolute terms, the level of innovation in the EU has remained stable. However, China's increase in global patent applications has led to a fall in the world share of transnational patents filed by the EU and the US respectively – in the EU's case, from approximately 32% in 2010 to 23% in 2020. By 2020, China had begun to catch up with both the 27 and the US, reaching a global share of transnational patents of 23% (up from a mere 7% in 2010).

On **green transition**-related global patent applications, Figure 11 shows that the EU has maintained its leadership in terms of technology generation. However, its global share of transnational patents has fallen from above 30% in 2010 to 24% in 2020, a similar trend to that of the US. In parallel, China's contribution has increased from about

[34] Pact for Skills – Skills Partnership for the Retail Ecosystem
[35] https://data.jrc.ec.europa.eu/collection/id-0130
[36] As a disclaimer, it should be noted that the use of patent data has some drawbacks. First, some companies may decide to pursue other strategies to market their inventions beyond patenting them. Second, the volume of transnational patents filed by each country does not speak necessarily to the quality of those same patents. Nevertheless, patent data is a widely used measure for tracking technological development activities, and by focusing on transnational patents (which are more expensive to file and maintain), we ensure that these patents are valid in more than one national market and that they are worth the investment needed to protect it.

4% in 2010 to more than 15% in 2020. The EU's leadership can be largely attributed to its strong innovation capacity in Renewable Energy Technologies, especially wind power, where it has a world share of patents of 62%. However, the EU is now head-to-head with China as regards solar power (with both having shares of approximately 27%). It should also be noted that the US has a much more competitive position in terms of energy-saving technologies, with a share of global patents of 41.3%.

Figure 11: World share in patent applications of the EU, US and China in green transition related technologies



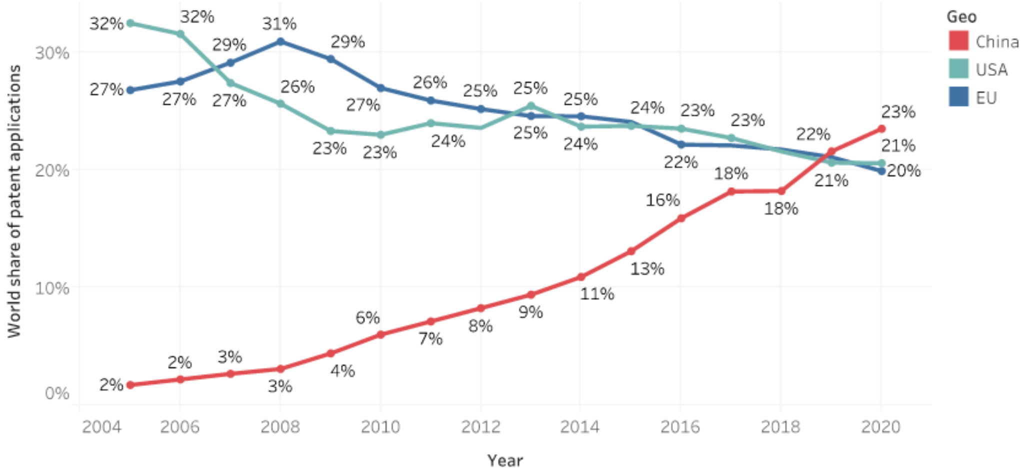
Source: Fraunhofer ISI based on Patstat for the European Monitor of Industrial Ecosystems (EMI) project 2023

In the **digital domain**, Figure 12 shows that, in aggregate terms, the EU's share has neither fallen faster than that of the US over the last fifteen years, nor has the absolute level of technology generation fallen. This is partially due to the fact that it has maintained its edge in Advanced Manufacturing technologies and IoT. However, the EU has lost ground in the field of Robotics, where China now leads with a global share of 30%.

Additionally, the EU is visibly behind both China and the US in AI and Big Data (China is in the lead in AI with a share of 31%, whereas the US is in the lead in Big Data with a share of 28%). This is particularly relevant given the role of these technologies in operations or approaches that are key to making industry more competitive, such as data management and analysis, predictive maintenance, human-machine collaboration, and error and resource minimisation.

The EU is also less competitive innovation-wise in the domains of Micro- and Nanoelectronics, Photonics, and Advanced Materials, where Japan is in the lead. Japan is especially competitive in Advanced Materials, where it boasts a share of 37%, but in Micro- and Nanoelectronics, it is head-to-head with China. As regards Biotechnology, US leads with 44% of transnational patents.

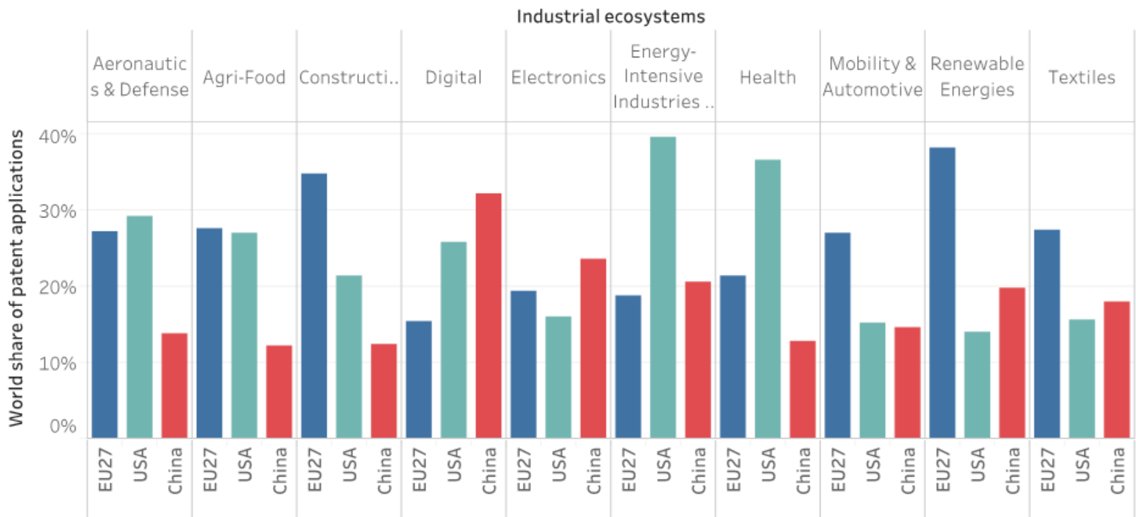
Figure 12: World share in patent applications of the EU, USA and China in digital technologies



Source: Fraunhofer ISI based on Patstat for the European Monitor of Industrial Ecosystems (EMI) project 2023

When looking at patent data per industrial ecosystem, the EU displays a relatively strong technological position globally in various industrial ecosystems, notably in aerospace and defence, agri-food, construction, renewable energies, mobility, and textiles. However, it trails behind the US and China in the digital ecosystem.

Figure 13: World share of the EU, the US and China in transnational patent applications in industrial ecosystems related technologies and relevant for the digital and green transition (2018-20)



Source: Fraunhofer ISI, based on EPO PATSTAT, for the European Monitor of Industrial Ecosystems (EMI) project (2023)

3.2. EU capacity to produce technology-based products

KEY MESSAGES:

- The EU is relatively self-sufficient in most industrial ecosystems, but it has dependencies in Digital and Electronics and in individual technologies

- The EU maintains its ability to produce more than it imports as regards advanced manufacturing, robotics, energy-saving technologies, and renewable energy technologies.

- The EU produces considerably less than it imports in AI and Big Data.

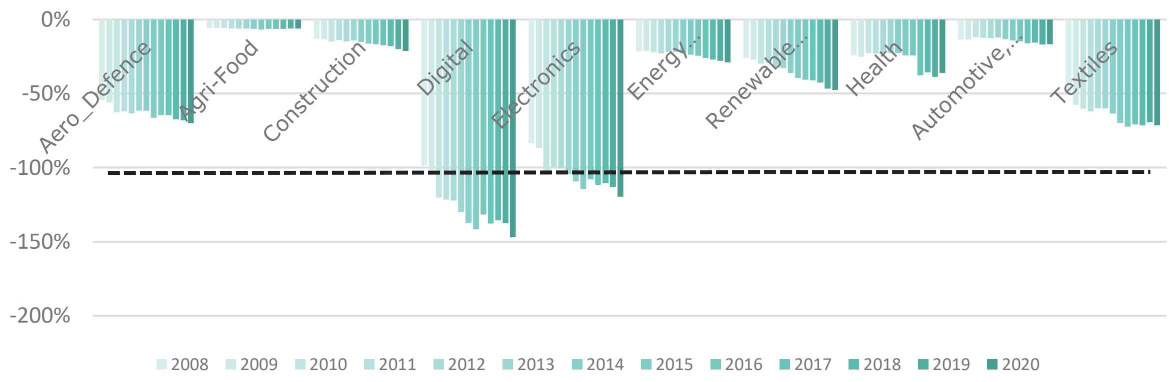
- The production of technology-based products and products that integrate advanced technologies has remained relatively stable over time.

- The EU has been able to translate its innovation capacity in advanced manufacturing and renewable energy technologies into marketable results.

Beyond innovation, actual production capacity matters to secure the EU's competitiveness and strategic autonomy. In this section, we provide data from Prodcom[37] as regards the self-sufficiency of the EU across the different industrial ecosystems and across different advanced technologies. For this, we analyse data on EU imports compared to EU-based production, as well as trade data from UNCOMTRADE. We complement these results with data on the weight of technology-based products and products that incorporate advanced technologies[38] in the overall production of the EU. This allows us to assess the EU's capacity to translate research into products.

Figure 14 shows that the EU remains comparatively self-sufficient in most industrial ecosystems. In six out of ten production-oriented ecosystems, the relation of imports to local production does not exceed 50%, even if it is in most cases increasing. The exceptions to this are Aerospace and Defence and Textiles, where the relation of imports to local production has exceeded 60% since the mid-2010s, and Digital and Electronics, where imports have exceeded local production since the early 2010s.

Figure 14: Ratio of EU imports to local EU production per industrial ecosystem from 2008 to 2020 (ratios above the -100% line indicate that the EU produced more than it imported in the technology at hand)



Source: Fraunhofer ISI, based on UNCOMTRADE, for the European Monitor of Industrial Ecosystems (EMI) project (2023)

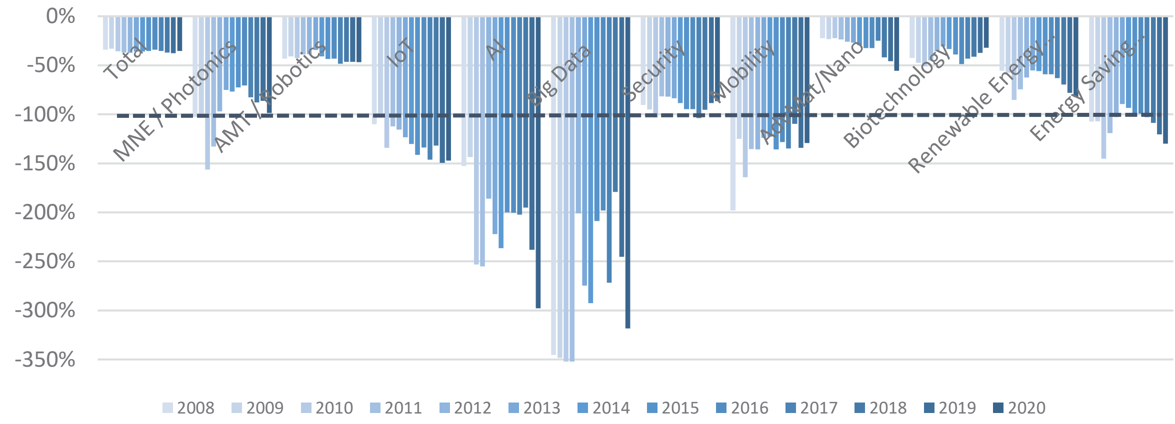
While most industrial ecosystems are relatively self-sufficient, this is less the case for individual advanced technologies.

[37] Prodcom is the title of the EU production statistics for Mining, Quarrying and Manufacturing, i.e., Sections B and C of the Statistical Classification of Economic Activities in the European Community (NACE Rev. 2). The headings of the Prodcom list are derived from the Harmonized System (HS) or the Combined Nomenclature (CN), which enables comparisons between production and trade statistics. The data only covers manufacturing goods, not services.

[38] Technology-based products are associated in whole or in a dominant part with the respective technology, i.e., they have these technologies as crucial components, unlike products that simply incorporate advanced technologies

Figure 15 shows the ratio of net imports in each technology in relation to local production of this same technology for each year from 2008 to 2020. Europe produces more than it imports in advanced materials and nanotechnology, biotechnology, advanced manufacturing and robotics, and renewable energy technologies. However, as regards products directly based on digital technologies such as AI or big data, net imports are high in relation to local production. Moreover, in the two main areas related to the green transition (renewable energies and energy saving technologies), ratios of net imports to local production have also increased, as have those in Advanced Manufacturing, indicating an increasing dependence on imports. On the other hand, as regards Microelectronics and Digital Technologies for Mobility, ratios of net imports to local production have decreased somewhat, suggesting an increase in self-sufficiency.

Figure 15: Ratio of EU imports of advanced technologies to EU production of those technologies from 2008 to 2020 (ratios above the -100% line indicate that the EU produced more than it imported in the technology at hand)

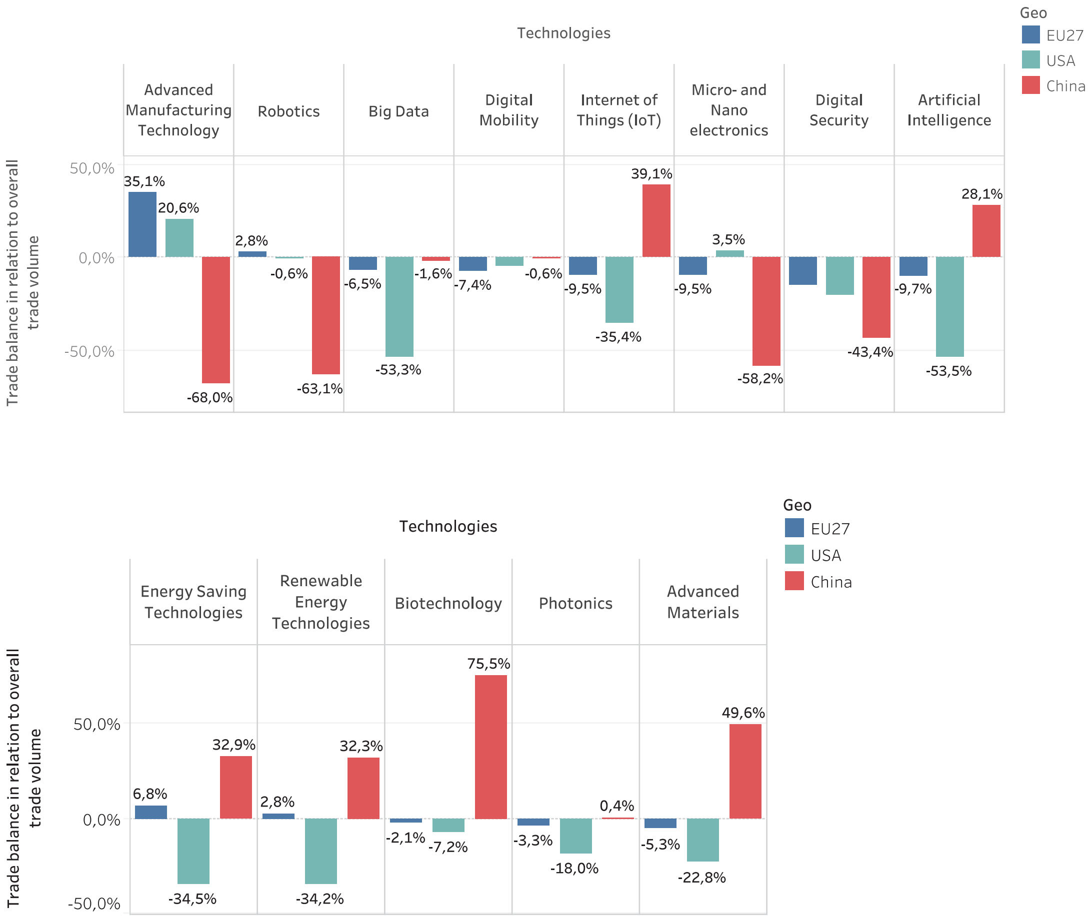


Source: Fraunhofer ISI, based on UNCOMTRADE, for the European Monitor of Industrial Ecosystems (EMI) project (2023)

These findings are complemented by the analysis of trade data sourced from UNCOMTRADE[39], which shows that the EU is exporting more than both China and the US as regards advanced manufacturing and robotics. The EU is a net exporter in two other technology areas, i.e., renewable energy technologies and energy-saving technologies (in which, however, China has overtaken the EU). China, on its part, registered significant trade surpluses and is ahead of both the US and the EU on a wide array all technologies, particularly in Biotechnology, Advanced materials and Nanotechnology, IoT, and AI. However, it has significant trade deficits in Digital Security and Micro- and Nano-engineering both of which are considerably higher than the trade deficits recorded by both the US and the EU, and in advanced manufacturing and robotics.

[39] It is not possible to show the the ratio of US or Chinese imports of technology-based products to US or Chinese production of the latter, because Prodcom data (related to production) only covers the EU. Therefore, we use UNCOMTRADE data to measure US and Chinese capacity to produce technology-based goods vis-à-vis the EU.

Figure 16: Trade balance in relation to overall trade volume – comparison between EU27, China and USA

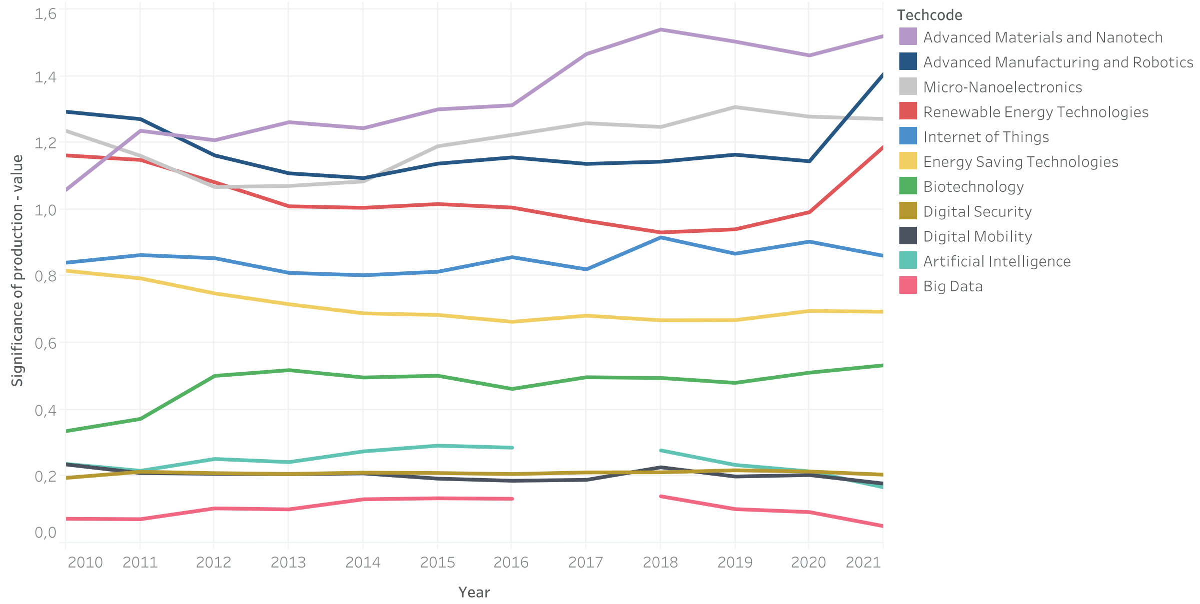


Source: Fraunhofer ISI, based on UNCOMTRADE, for the European Monitor of Industrial Ecosystems (EMI) project (2023)

As regards the EU's capacity to translate research into products, Figure 17 below shows that technology-based goods represented 6.32% of overall EU production of manufacturing goods in 2021.. Of this share, in 2021, key technologies included advanced manufacturing and robotics (1.5%), advanced materials and nanotechnology (1.4%), micro- and nanoelectronics and photonics (1.3%), and renewable energy technologies (1.2%). Between 2010 and 2021, the share of products directly based on advanced technologies increased 0.76%, with advanced materials and nanotechnology, and renewable energy technologies showing a particularly strong increase over the period of 2020 to 2021.

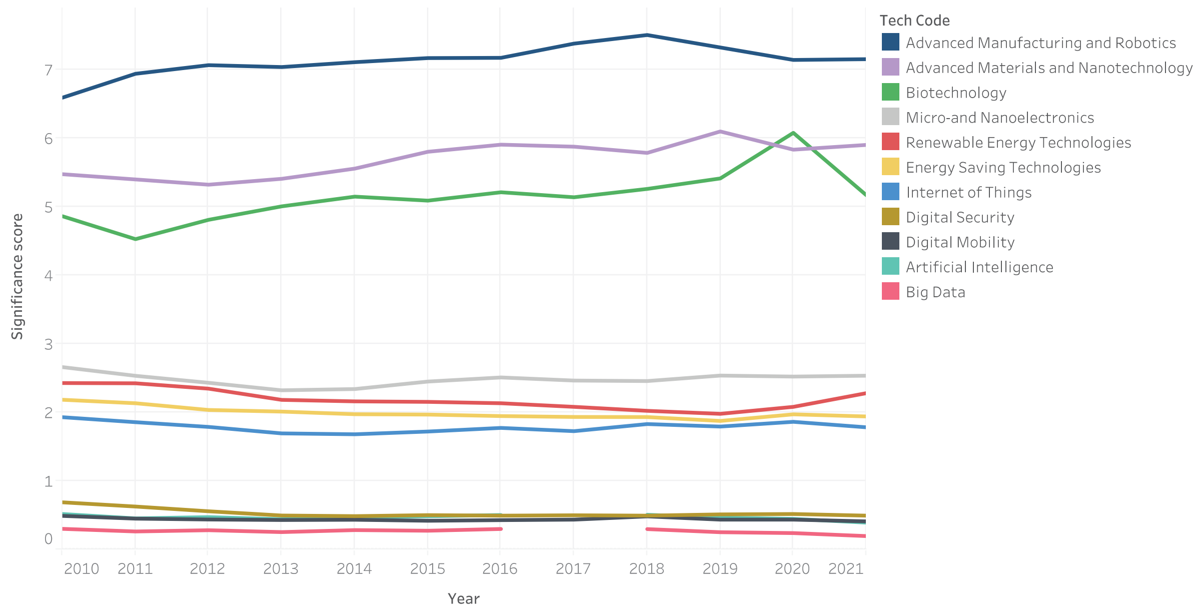
Products that integrate advanced technologies represented 19.3% of total EU production of manufacturing goods in 2021. Figure 18 below shows the importance of advanced manufacturing and robotics, advanced materials and nanotechnology, and biotechnology compared to other technologies. Over time, the relative importance of products that indirectly incorporate these technologies in the EU's overall production fell slightly. Values remain quite stable for most technologies, with the exception of biotechnology, which shows a strong decrease over the period of 2020 to 2021, and of renewable energy technologies, which shows a slight increase in recent years.

Figure 17: Technology-based goods as a percentage of total EU production over the period 2010-2021



Source: IDEA Consult based on Eurostat [prom], for the European Monitor of Industrial Ecosystems (EMI) project (2023)

Figure 18: Production of goods incorporating advanced technologies as a percentage of total EU production over the period 2010-2021



Source: IDEA Consult based on Eurostat [prom], for the European Monitor of Industrial Ecosystems (EMI) project (2023)

3.3. Scaling-up capacity in the EU

KEY MESSAGES*:*

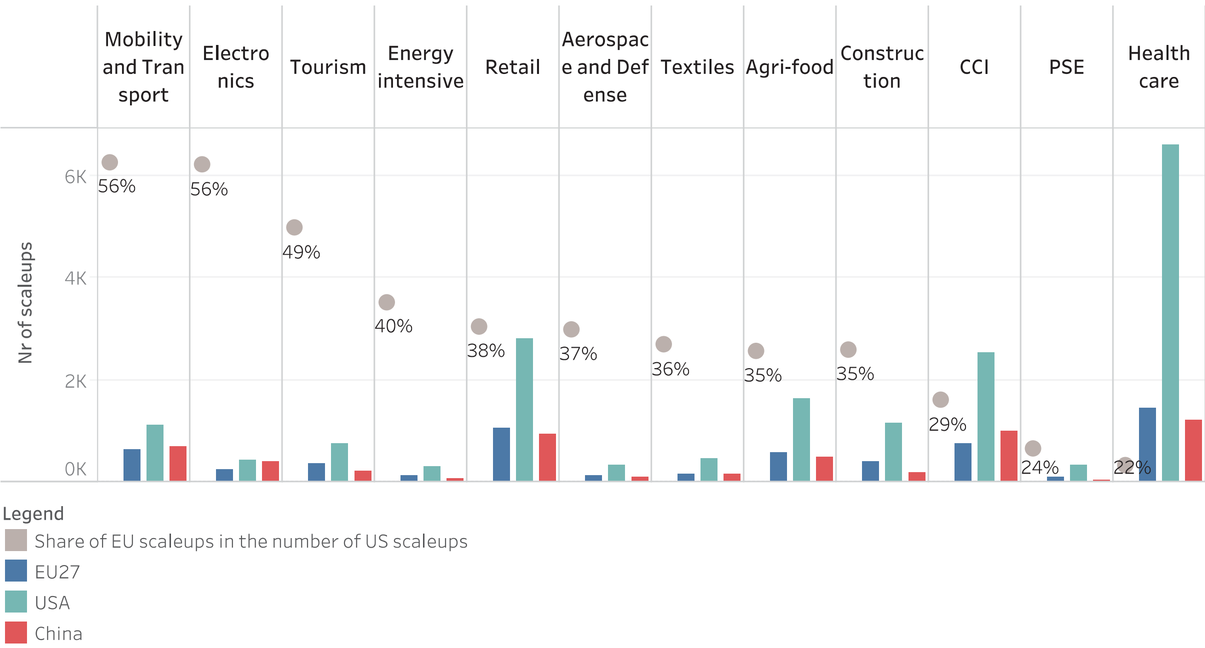
- The US has considerably higher number of scale-ups than the EU.

- A deeper analysis reveals that the EU-US gap is narrowing, particularly in Mobility, Transport and Automotive, Electronics, Tourism, and Energy-intensive Industries.

Scale-ups are key drivers of innovation in any industrial ecosystem, as they push other industrial firms to adopt their production and operation models. This section reviews the number of active scaleups per industrial ecosystem in the EU, the US, and China[40], based on Crunchbase data[41].

Figure 17 below shows the number of scale-ups for the EU, the US, and China in absolute terms across the different industrial ecosystems. The US has a much larger number of scale-ups than the EU across all industrial ecosystems. However, the gap is smaller in some ecosystems than in others. The gap is particularly large in the healthcare ecosystem (where the number of EU scale-ups is 22% of the number of US scale-ups) and smallest in mobility (where it is 56% of the number of US scale-ups).

Figure 19: Number of scale-ups related to twin transition technologies per industrial ecosystem in the EU, US and China and ratio of EU scaleups to US scaleups per industrial ecosystem



Source: Technopolis Group, Crunchbase, 2023, for the European Monitor of Industrial Ecosystems (EMI) project (2023)

However, an analysis of Crunchbase suggests that the gap is narrowing with the US both in start-ups and scale-ups. This trend is particularly relevant for Mobility, Transport and Automotive, Electronics, Tourism, and Energy-intensive Industries. At the start of 2023, and according to data collected by the Commission's First SDD Report,

[40] A disclaimer must be made regarding the data presented for China: the data shown refers to scale-ups that are registered on the Crunchbase database, on which Chinese companies are not properly represented

[41] Crunchbase is a platform that provides business information on private and public companies, especialy in the tech industry.

only 249 unicorns[42] were based in the EU as compared to 1,444 in the US and 330 in China.[43] The largest EU unicorns include companies from the energy, retail, ICT, and mobility industries. Further information provided by the SDD Report acknowledges that the EU seems to have progressed well recently with respect to the Digital Decade target of 500 unicorns to reach by 2030, with analysts pointing also to a strong growth in the number of EU-based unicorns in the past decade. The report mentioned that should this trend continue,[44] the EU is likely to meet the Digital Decade target on the number of unicorns in two years. Despite this, the report recommends further effort for the EU to achieve a leadership position on the global stage, facilitating the growth of the Union's innovative scale-ups and improving their access to finance.[45]

42 EU unicorn numbers stated are for EU-founded companies that continue to have their HQ in the EU.
43 2023 Report on the state of the Digital Decade | Shaping Europe's digital future (europa.eu), P.20. Source: Dealroom.
44 See C(2023) 7500 'Communication from the Commission establishing the Union-level projected trajectories for the digital targets' on the volatility of the trend over the past few years.
45 2023 Report on the state of the Digital Decade | Shaping Europe's digital future (europa.eu), P.20

ANNEX

Introduction of the measurements and NACE 2 codes used to monitor industrial ecosystems towards green and digital transition

The methodology builds on the definition of industrial ecosystems outlined in the 2021 and 2022 Annual Single Market Reports (ASMR), taking into account the key performance indicators and the methodology presented for constructing the data used for the analysis of industrial ecosystems.

The industrial ecosystems methodology aims at analysing the EU economy. It extends and complement the mostly linear approach typical of value chain analysis to highlight the network of complex interlinkages between economic actors across sectors and regions. The identified industrial ecosystems have a marked pan-European nature, but their composition is very heterogeneous in terms of sectoral composition, size and scope. Industrial activities represent a significant share of course, but services play a fundamental role. SMEs represent a very significant share of these ecosystems, up to 99% in the case of tourism. The ecosystems do not cover the whole economy. Notably, the financial sector and most of the public sector are not included.

Ecosystems are linked to each other. For instance, the Retail ecosystem provides (downstream) services to virtually all other ecosystems. Similarly, the Energy Intensive Industry ecosystem supplies inputs to many other ecosystems. Moreover, ecosystems overlap with each other, as some activities are relevant for more than one;

The statistical definitions of the industrial ecosystems as laid down in the ASMRs have the following characteristics:

- They are based on 2-digits NACE classification. While a list of 4-digits sectors was initially used, data is not available for all sectors at such level of disaggregation.
- Whenever a 2-digits sector is considered too large or heterogeneous, a share was calculated using these possible approaches:
  - Whenever possible, we identified the appropriate 4-digit sectors and calculated their share into the corresponding 2-digit sector. For that operation, we used data from the Structural Business Statistics. Weights were calculated for both Value Added and Employment.
  - Use of specialised knowledge (specific studies or contacts with industry).

As noted in Annual Single Market Report (ASMR) 2022[46], the data used to compile indicators on the ecosystems are derived from official statistics, including national accounts, Structural Business Statistics, and short-term business statistics. These statistical sources use the NACE rev.2 classification to identify enterprises according to their main activity.

It is important to note that this level of granularity is not optimal to identify all the elements of the ecosystems, but most of the data sources used to calculate indicators are only available at the 2-digits level and therefore this affects the precision of the indicators.

The indicator framework used by EMI for the monitoring of twin transition includes the same NACE rev.2 classification as in ASMR 2021 by using a set of traditional and novel data sources that allow shedding new light on ongoing transformation patterns. However, the novelty of the analysis lies in the exploratory and innovative data sources such as Crunchbase, Exiobase and Linkedin, used across the different pillars of the analysis. These new sources of data allow to explore new areas of measurement for the green and digital transition that has not been

[46] DocsRoom - European Commission (europa.eu)

analysed yet by any other Commission initiative or observatory. In addition, the data provided is industrial ecosystems specific which also brings a new perspective to monitor twin transition over time.

Lastly, the analysis covers a list of technologies that support twin transition. These lists of technologies were selected among others as being the most strategic technologies for the competitiveness of the EU Internal Market. The list is defined as advanced technologies, and it is divided in two groups; technologies that support digital transformation and technologies that support green transformation.

Digital transformation		
	1	**Advanced Manufacturing and Robotics**
		Advanced Manufacturing (ICA and Mechanical Engineering)
		Robotics
	2	**Artificial Intelligence**
	3	**Augmented and Virtual Reality**
	4	**Big Data**
	5	**Blockchain**
	6	**Cloud technologies**
	7	**Digital Security & Networks/ Cybersecurity**
	8	**Internet of Things**
	9	**Micro- and Nanoelectronics & Photonics**
	10	**Online platforms**
Green transformation		
Green technologies	11	**Advanced Materials and Nanotechnology**
	12	**Biotechnology**
	13	**Energy Saving Technologies**
	14	**Renewable Energy Technologies**
		Solar Power
		Wind Power
		Other (geothermal, hydropower, biomass)
	15	**Clean Production Technologies**
	16	**Recycling Technologies**
Circular business models		**Circular business models including:** Remanufacturing Renting, leasing and related service models Repair and maintenance services Resell, reuse Circular design (products that can be disassembled and recycled) Design for durability (products that can last longer)

List of indicators used in this report

Indicator	Source	Time series
Production global competitiveness: AT country share in global production of manufacturing goods	Prodcom	2015-2020
Production country significance: Share of production in AT over a country's total production of manufacturing goods	Prodcom	2015-2020
Trade	UNCOMTRADE	2015-2020
Global emissions	Exiobase	2015-2021
Material consumption	Exiobase	2015-2021
Share of renewable energy	Exiobase	2010-2019
Environmental management: Number of organisations with registered environmental management system ISO 14001, EMAS and other	ISO	2010-2021
Use of circular technologies and business models	Survey	2023
Inventive activity global competitiveness: twin technology share in global patenting	Patstat	2015-2020
Inventive activity global competitiveness: AT country share in global patenting in Advanced Materials, Photonics, Biotechnology related to Green transition	Patstat	2015-2020
Technology startups: Number of technology startups generating technologies; share in total start-ups	Crunchbase	2010-2022
Technology startups: Number of technology startups generating technologies; share in total start-ups	NetZero	2010-2022
Technology adoption: Share of companies adopting advanced (and basic) technologies	Survey	2023
SMEs and Large company Private equity and Venture Capital (VC): Value of private equity and VC funding raised in technologies supporting the digital transition	Crunchbase	2015-2022
SMEs and Large company Private equity and Venture Capital (VC): Value of private equity and VC funding raised in technologies supporting the digital transition	NetZero	2015-2022
Private investment in transition	FDI insights, Trendeo	2016-2022
Number of twin transition public procurement notices	TED (+ National)	2022-2023
Supply of professionals – share of professionals with twin transition skills within total economy	LinkedIn	2019-2022
Share of professionals with twin transition skills within IE total	LinkedIn	2019-2022
Demand for professionals (basic to advanced digital transition expertise)	Cedefop	2022