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COMMISSION STAFF WORKING DOCUMENT

Second 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 2025 Annual Single Market and Competitiveness Report"

COM(2025) 26 final – SWD(2025) 11 final – SWD(2025) 12 final

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The 2025 Annual Single Market and Competitiveness Report

{COM(2025) 26 final} - {SWD(2025) 11 final}

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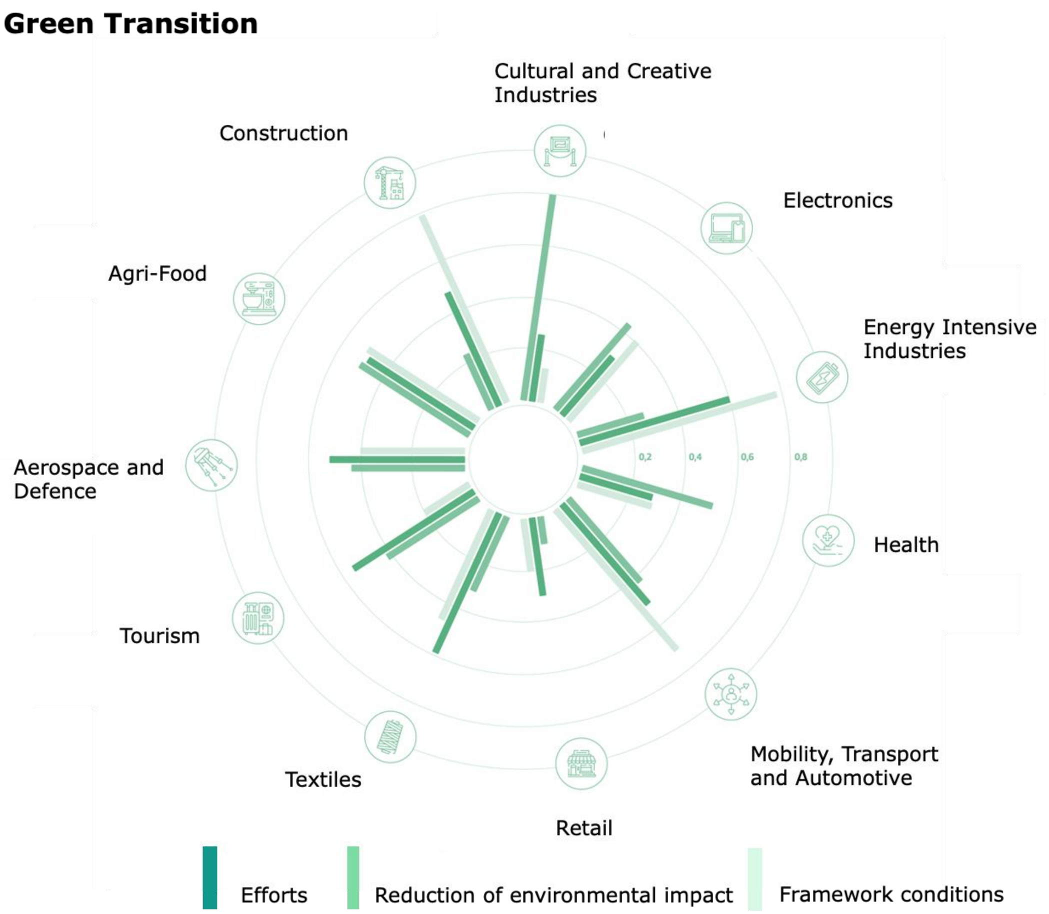
Executive summary

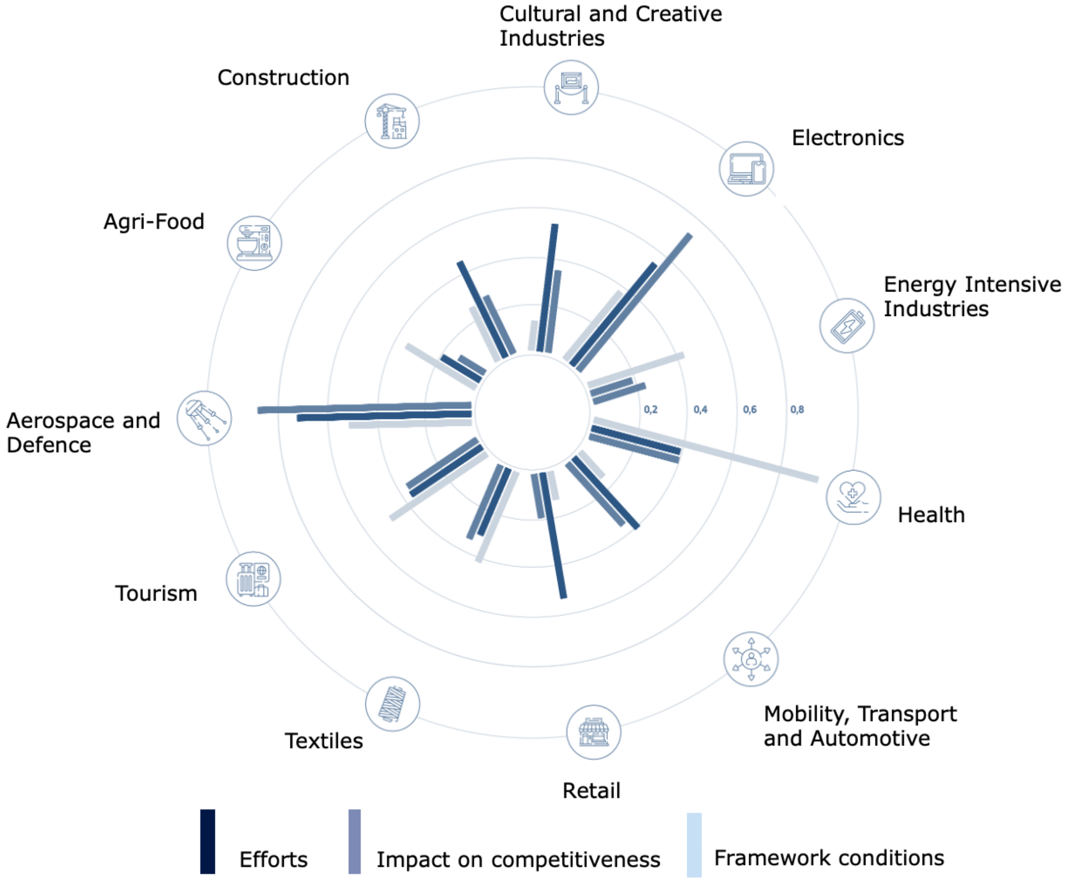
The European Monitor of Industrial Ecosystems (EMI) aims to inform EU policymakers, industry, and Member States about developments in the twin transition across industrial ecosystems[1]*, and about EU competitiveness.*

This annex contains the second annual report on EMI findings. For greater clarity, the analysis is now divided into two sections on the 'green transition' and the 'digital transition', each showing: a) industry efforts, b) framework conditions and c) the impact on environmental and productivity. The third section collates these results in the form of composite indicators indicating overall progress in each industrial ecosystem.



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

Digital Transition



The **key findings** of this year's analysis are that on the **green transition**:

- across industry, progress has been mixed in the rate of adoption of green technologies, with notable efforts made in the aerospace and defence sector;
- the level of private-sector investments in the green transition remains relatively low in the majority of industrial ecosystems;
- the share of green tech start-ups rose significantly from 2015 to 2022 but fell in 2023;
- the EU has become a net importer of key green technologies, notably renewable energy technologies and energy-saving technologies;
- both the supply and demand for green transition skills remains low;
- EU industrial ecosystems are making uneven progress in reducing their impact on the environment, with faster reductions in service-based ecosystems than in manufacturing.

On the **digital transition**:

- 2023 witnessed a leap forward in the adoption of several advanced digital technologies. Aerospace and defence, electronics and the cultural and creative industries recorded an average increase of over 10% since last year.

However, the level of private-sector investment in the digital transition remains low. Nearly half of businesses invest less than 1% of their annual turnover in advanced digital technologies.

The number of digital tech start-ups increased significantly in 2023, particularly in service industrial ecosystems.

The EU's share of global digital patent applications is falling but is still on par with global competitors.

The share of digital technology-based goods in total EU production has risen by 28% since 2011 but is still relatively low at 4.83%.

Unlike for green skills, there is much higher demand for advanced digital skills. The supply of professionals with advanced digital skills increased from 18-20% between 2022 and 2024.

The adoption of digital technologies has led to significant productivity increases over the past year, particularly in electronics, aerospace & defence, and health. Robotics recorded the greatest impact on productivity in manufacturing ecosystems and artificial intelligence in services-based ecosystems.

Green transition of industrial ecosystems

2.1 Industry efforts to transition to sustainable industry

- Across industry, **progress has been mixed in the rate of adoption of green technologies**, with the largest in the aerospace and defence and energy-intensive ecosystems.

- Overall, the level of **private-sector investment in the green transition remains relatively low**. In terms of venture capital investment in green transition-related technologies, investment levels are below US levels, but the EU maintains its lead position in venture capital investments in clean production technologies.

- The share of **green tech start-ups rose significantly from 2015 to 2022,** but fell in 2023.

- In terms of green technology generation, the EU continues to demonstrate global strength in its share of worldwide patent applications related to the green transition. Energy-intensive industries are notable examples here.

- The share of **green technology-based products** in overall EU production **increased only slightly between** 2015 and 2023.

- Despite this, the EU has become **a net importer of key green technologies**, notably renewable energy technologies and energy-saving technologies.

This section examines industry efforts in the green transition based on:

- i) progress in adopting environmental technologies[2] and environmental measures[3];
- ii) the level of company investment in the green transition, including green technologies, renewable energy and circular economy solutions;
- iii) an analysis of how start-ups that provide environmental solutions for businesses contribute to the transformation of the industrial value chain;

[2] Such as advanced materials, biotechnology and energy-saving technologies, renewable energy technologies.
[3] Such as saving water, using renewable energy and minimising waste.

- iv) the level of technology generation (green technology-related patents);
- v) information shedding light on the production of green technology-based products relevant to the manufacturing industries.

Adoption of green technologies

This subsection presents the rate of adoption of environmental measures and green technologies as reported in the Eurobarometer survey on SMEs, resource efficiency and green markets[4]. Where data were not available, the project has complemented the gaps through a dedicated survey[5].

Industries across all ecosystems have adopted a range of environmental measures to reduce their environmental impact. The most common resource efficiency actions include saving energy (66%), minimising waste (66%) and saving materials (57%).

Several manufacturing ecosystems made progress on environmental measures. In **aerospace and defence,** 26.6% of companies took energy-saving measures and 26.6% saved materials. 20% of **energy-intensive industries** moved to renewable energy and 22.9% took action to minimise waste.

However, service ecosystems have made **less progress**. The most common environmental action taken by this group of ecosystems is to switch to renewable energy.

Figure 1: Progress in the adoption rate of environmental measures in industrial ecosystems (percentage change, 2021-2024) (highlights indicate over 5% change in the share of companies taking action)

	Saving water	Saving energy	Using renewable energy	Saving materials	Switching to greener suppliers	Minimise waste	Selling residues waste to another company	Recycling by reusing material or waste	Designing products that are easier to maintain
Aerospace and Defence	31.6%	27%	11.5%	26.6%	16.3%	12.7%	12.9%	20.5%	12.8%
Agri-Food	-9,1%	5.3%	-6.5%	11.7%	-3.4%	-10.9%	-15.7%	-4.8%	-22.6%
Construction	1.3%	2.2%	2.3%	-0.9%	0.4%	3.3%	-2.9%	-1.6%	5.3%
Cultural and Creative	5.2%	0.2%	-2.9%	2.3%	-0.7%	2.4%	1.7%	-2.6%	-11.8%
Digital	-5.3%	-1.4%	1.5%	-4.7%	-7.9%	-1.9%	-2.3%	8%	-8%
Electronics	0.3%	15.8%	6.4%	-15.3%	28.5%	-19.3%	-18.4%	-2.2%	-0.3%
Energy - Renewables	8.2%	12.4%	19.3%	6.2	0.8%	1%	-7.1%	24.8%	23.2%
Energy Intensive Industries	11.5%	12.8%	20%	12%	2%	22.9%	5.2%	1.4%	11.1%
Health	-3.1%	0.1%	18.1%	-32%	4.1%	-30.8%	-13%	-32.9%	2.9%
	9.8%	11.3	1%	6.2%	3.5%	6.4%	-3.5%	4.7%	4.4%
Mobility, Transport and Automotive	19.1%	17%	0.6%	4.6%	8.6%	9.2%	9.9%	-1.2%	11.2%
Proximity & Social Economy	-0.9%	4.4%	8.2%	-1.1%	0.9%	-0.7%	0.4%	2.5%	5.6%
Retail	17.8%	7.8%	17.2%	-2.7%	1.9%	-0.2%	5.6%	4.2%	-16.6%
Textile	-1.5%	1.8%	6.2%	-2.1%	-1.5%	1.5%	-2.1%	3.4%	3.2%

Below -20% | Below -10% | Below 0% | Above 0% | Above 10% | Above 20%

Source: Eurobarometer 2024 on resource efficiency and green markets

[4] SMEs, resource efficiency and green markets - October 2024 - - Eurobarometer survey (europa.eu)

[5] The EMI survey is an in-house business survey that collects data on the level of change towards the green and digital transition of European businesses across twelve industrial ecosystems and gathered opinions on the related investments and expected future developments. The survey used computer-assisted telephone interviewing, with an overall sample of 4 000 respondents.

When looking at the adoption rate of environmental technologies, some progress has been made in the field of **energy-saving technologies**, in particular in aerospace and defence where 89% of companies have adopted at least some type of technology and energy-intensive industries (55%). There was also progress on advanced materials, adopted by 55% of aerospace and defence companies and by 33% of energy-intensive industries.

However, again **the up-take is lower in services ecosystems.** The adoption rate in most services ecosystems is below 50%, except in the cultural and creative industries where 54% of businesses adopted recycling technologies.

Figure 2: Adoption rate by industrial ecosystems of environmental technologies in 2024

Progress in the adoption rate of green technologies across industrial ecosystems

	Energy Saving Technologies	Recycling Technologies	Advanced Materials	Clean Production Technologies	Biotechnology
Aerospace and Defence	88.89%	55.56%	55.56%	44.44%	11.11%
Agri-Food	52.92%	55.64%	26.07%	31.13%	15.95%
Cultural and Creative Industry	45.43%	54.26%	20.50%	17.67%	2.84%
Construction	42.49%	41.45%	23.32%	16.58%	2.59%
Electronics	45.81%	54.19%	18.99%	16.76%	3.35%
Energy Intensive Industry	55.24%	61.90%	32.86%	38.10%	7.14%
Health	59.38%	65.63%	29.17%	39.58%	20.83%
Mobility Transport and Automotive	41.62%	49.75%	20.30%	20.30%	3.55%
Retail	33.00%	38.61%	14.85%	15.51%	3.30%
Proximity, Social Economy and Civil Security	42.06%	51.40%	7.48%	4.67%	0.00%
Textile	47.52%	56.44%	28.71%	24.75%	7.92%
Tourism	39.89%	46.45%	18.03%	9.84%	3.83%

0% < 25% 25% < 50% < 50% Highlights of more than 5% change in the share of enterprises taking actions

Source: EMI Enterprise Survey, 2024

Private-sector investment in the green transition

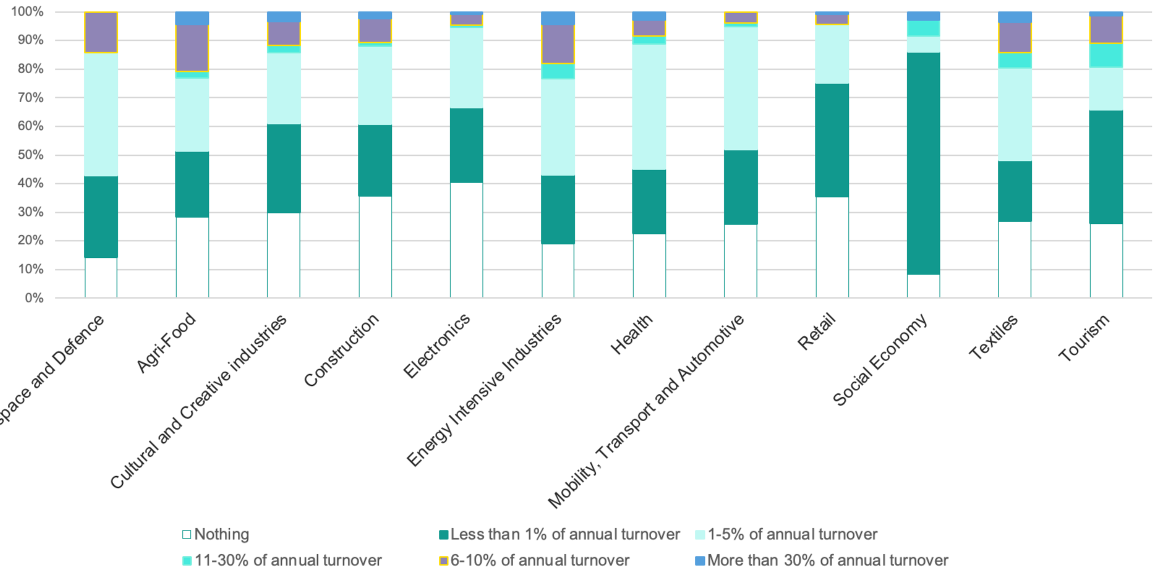
This subsection monitors the scale and type of investment in environmental technologies and new business models in the EU and across the industrial ecosystems. It draws on data sources such as Crunchbase data[6], an EMI survey, and the Eurobarometer on resource efficiency referred to above. Note that data in both surveys include all business sizes (SMEs, mid-caps and large firms).

The level of investment is still relatively low. Around 30% of businesses invest between 1% and 5% of their annual turnover in environmental technologies and green transition initiatives, around 30% invest less than 1% and 30% are not investing in these areas at all. Only three ecosystems invest over 30% of their turnover in green transition technologies (though this seems to be concentrated in a few companies): agri-food (16%

[6] The scope of our analysis on green transition investments encompasses a range of areas including advanced materials, energy-saving technologies, biotechnology, clean production technologies, waste management solutions, carbon capture technologies, and circular industrial business models.

of businesses), energy-intensive industries (14% of businesses) and textiles (11% of businesses).

Figure 3: Investment in green transition activities



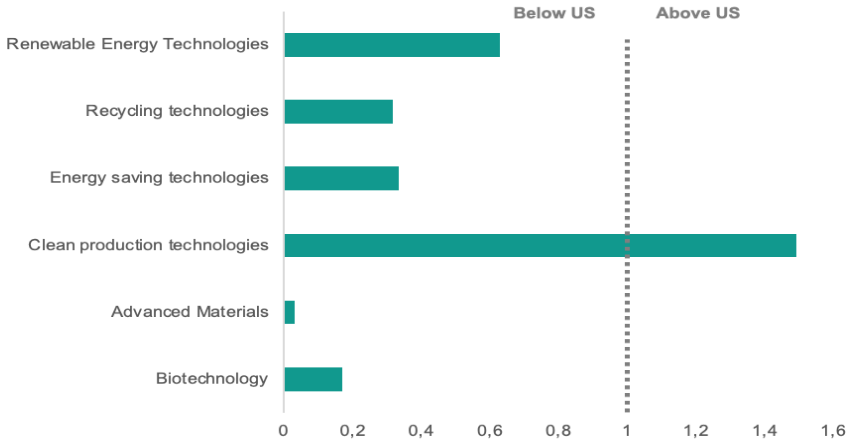
Source: EMI enterprise survey (2024). Note: For this survey question only social economy organisations have been surveyed and not the whole ecosystem. For the health sector, the survey focused on pharmaceutical and medical device companies.

Business investment in the green transition by businesses across the 12 industrial ecosystems[7] are estimated at approximately EUR 69 billion. Short-term future investment plans indicated in the survey suggest **no significant changes by businesses for the coming year**.

Other financial solutions, such as **venture capital investment**, play a critical role in providing companies, especially innovative start-ups, with access to capital. There is higher venture capital investment in the EU in clean production technologies (measured as a percentage of GDP in absolute terms) than in other global competitors, but **the US is closing the gap**. In the other green technologies, including renewable energy, recycling, energy-saving technologies, and advanced materials, **investment is lower in the EU** despite the EU's relatively strong position in technology generation.

Figure 4: Ratio of venture capital in the EU/US, 2021-2024 (normalised per GDP)

[7] The EMI project analyses the twin transition of 12 industrial ecosystems and tackles the performance for digital and energy-renewables ecosystems horizontally, meaning both ecosystems are analysed in all industrial ecosystems reports. For more information about the EMI monitoring framework, see (https://monitor-industrial-ecosystems.ec.europa.eu/about/monitoring-framework).



Source: Technopolis Group based on Crunchbase for the European Monitor of Industrial Ecosystems (EMI) Note: Ratios measured for the period 2021-2024 as a percentage of gross domestic product.

The green tech start-up ecosystem

This section presents the share of green tech start-ups in services and manufacturing ecosystems and assesses the trends over the 2015-2022 period. The data is taken from Crunchbase.

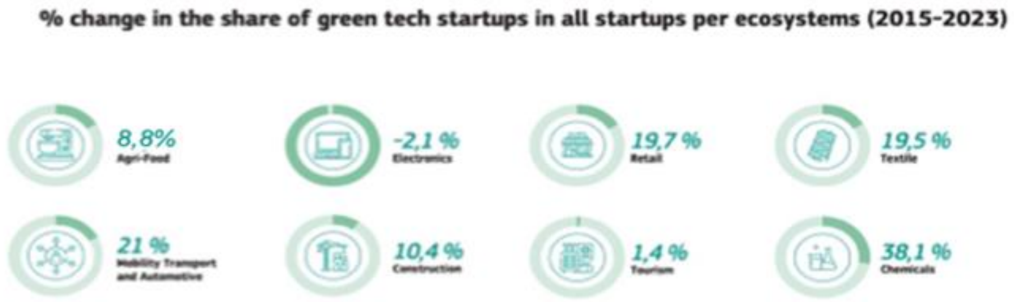
EU green tech start-ups are developing technologies that can be implemented by service and manufacturing businesses. They are collaborating with manufacturers and service providers to incorporate cleaner production processes, such as using bio-based or recycled materials, implementing solutions to optimise energy use, and deploying internet of things (IoT)-enabled sensors to monitor and minimise their environmental impact. Many of these start-ups are also working on eco-friendly packaging solutions, alternative energy sources and solutions that facilitate the reuse of products, fostering a more circular approach to manufacturing.

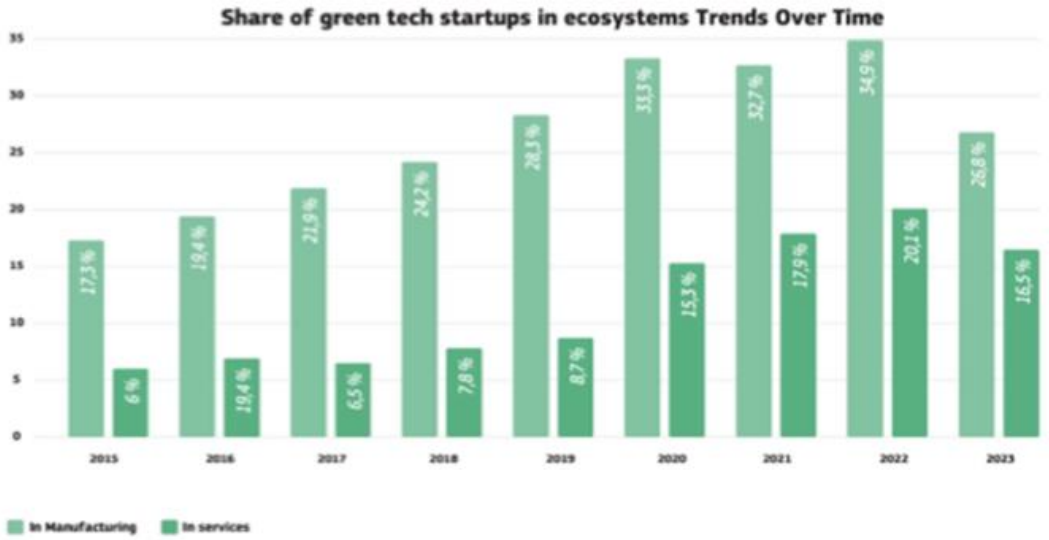
The share of EU green tech start-ups has risen significantly from 2015 to 2022. This reflects the way in which green tech solutions have become more integral across industry. However, over the past year there has been **a decline in the percentage of green tech start-ups**, falling by 8 percentage points to around 27% for manufacturing ecosystems and by 4 percentage points to around 17% for service ecosystems.

This drop parallels the fall in the overall volume of EU venture capital in 2023, which is also identified in the 2025 Annual Single Market and Competitiveness Report (ASMCR). Our analysis shows a particularly sharp decrease in venture capital and private equity funding in green tech companies from 2022 to 2023 in the mobility, tourism and agri-food ecosystems[8]. As highlighted in the 2025 ASMCR, the fact that the other major economies such as the US offer favourable funding environments (as illustrated by Figure 4 above) means EU green tech companies have an incentive to relocate or seek funding abroad.

Figure 5: Green tech start-ups supporting industrial ecosystems

[8] For a visual representation of these results, see the EMI Data Dashboard: https://monitor-industrial-ecosystems.ec.europa.eu/data-dashboard.





Source: Technopolis Group based on Crunchbase for the European Monitor of Industrial Ecosystems (EMI)

The industrial ecosystems that have seen the highest increase in green start-ups include energy-intensive industries in particular, due to the increasing importance of biotechnology. In the mobility, transport and automotive ecosystem, green tech start-ups tend to be in the electric vehicle and sustainable mobility service sectors. In some ecosystems, there are many fewer green start-ups, notably in aerospace and defence.

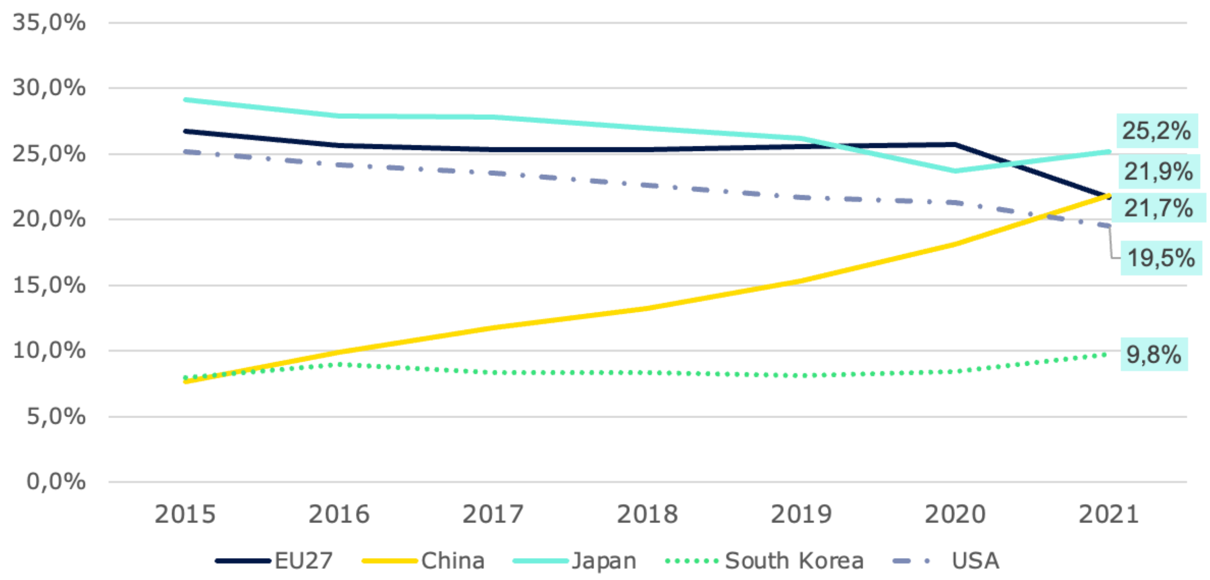
Green technology-related patents

This subsection analyses technology generation based on transnational patent data provided by the European Patent Office (EPO)'s Worldwide Patent Statistical Database[9], with the aim of assessing the EU's innovation capacity and competitiveness.

In terms of worldwide green technologies patent applications, in 2021, the EU's share (21.7%) was broadly level with Japan (25.2%), China (21.9%) and the US (19.5%). Since then, however, it has **fallen steadily**, as has the share for Japan and the US. By contrast, China's share of global patents in green technologies has increased significantly, and it is now head-to-head with the EU on this measure.

[9] Disclaimer: note that using patent data has some drawbacks. First, some companies may pursue other strategies to market their inventions beyond patenting them. Second, the volume of transnational patents filed by each country does not necessarily indicate the quality of the patents. Nevertheless, patent data is a widely used measure for tracking technological development activities. 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 are worth the investment needed to protect it.

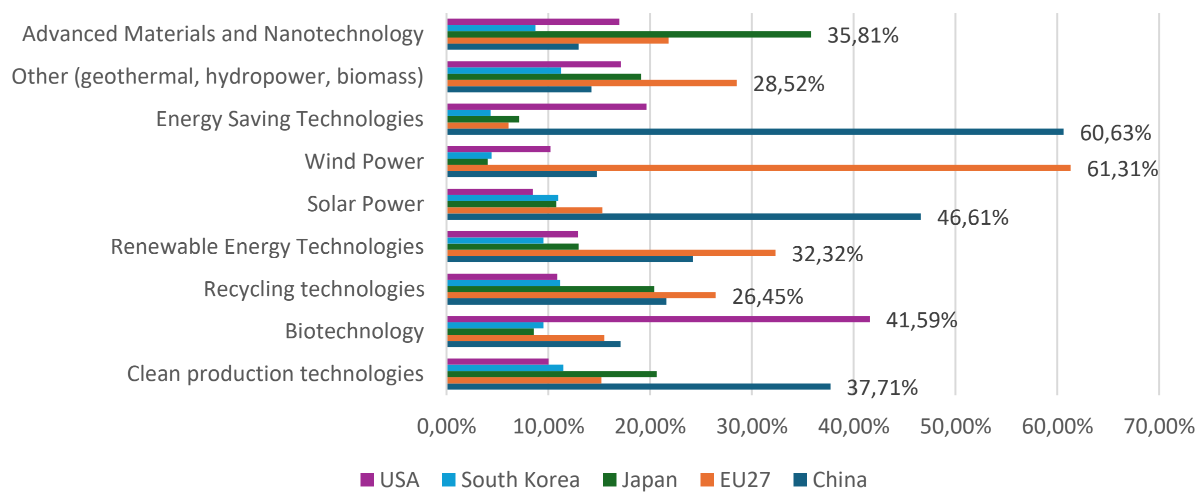
Figure 6: Global share of patent applications in green technologies



Source: Fraunhofer ISI, based on EPO PATSTAT for the European Monitor of Industrial Ecosystems (EMI)
Note: 2021 data for green technologies defined based on CPC Y-classes are estimates

On the specific technology fields, the EU has maintained a dominant position in renewable energies globally, especially in wind power (some 61% of all global patent applications) and other renewable energies such as geothermal or biomass-based processes (28.5%). The EU also maintains its lead in recycling technologies (26.5%). In solar power, however, China has overtaken the EU to reach almost half of all global patents. Similarly, in energy-saving technologies, the EU has a lower global share than both the US and China, with China having a 60.6% share. **The EU has lost considerable ground in both of these technology fields since 2005**, falling by around 20 percentage points on each measure.

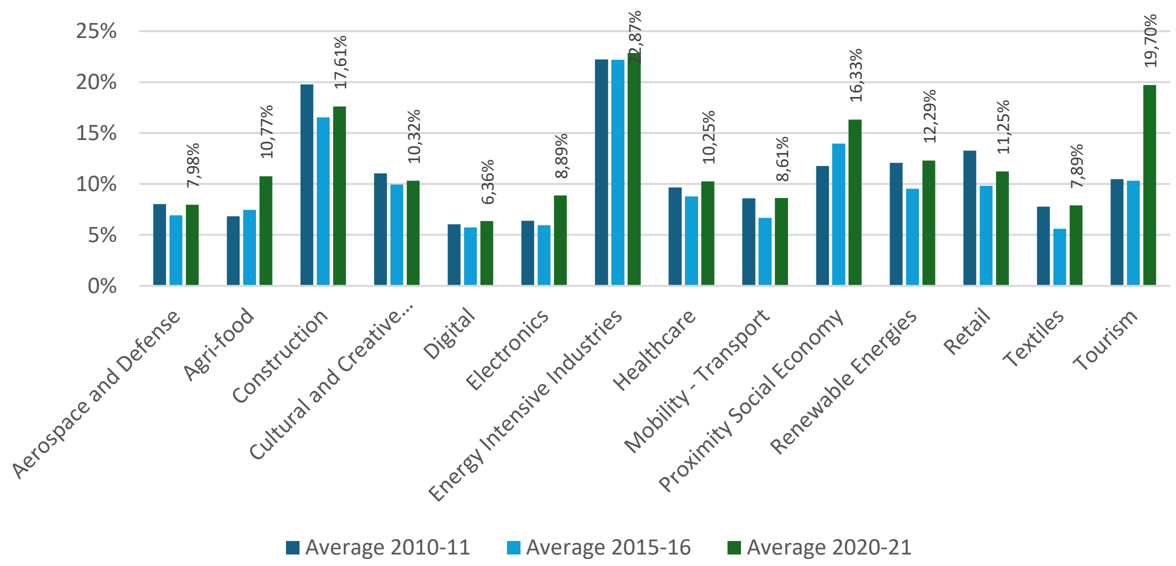
Figure 7: Global share of patent applications by specific green transition technology field



Source: Fraunhofer ISI, based on EPO PATSTAT for the European Monitor of Industrial Ecosystems (EMI)
Note: 2021 data for green technologies defined based on CPC Y-classes are estimates

The data also shows that **green patents play a significant role in the patent portfolios of specific industrial ecosystems**, accounting for over 15% of all patents in construction, energy-intensive industries, proximity and social economy and tourism, and over 10% in aerospace and defence, digital, electronics, mobility and textiles.

Figure 8: Share of 'green patents' in overall patent portfolio by ecosystem



Source: Fraunhofer ISI Analysis based on EPO PATSTAT and Moody's ORBIS for the European Monitor of Industrial Ecosystems (EMI)

However, with the exception of tourism, proximity and the social economy, agri-food and, to a lesser extent, the electronics ecosystems, the **share of green technology for patents relative to total patents has stagnated over the past decade**. Even these industrial ecosystems achieved only half the increase of digital patents.

Green technology production

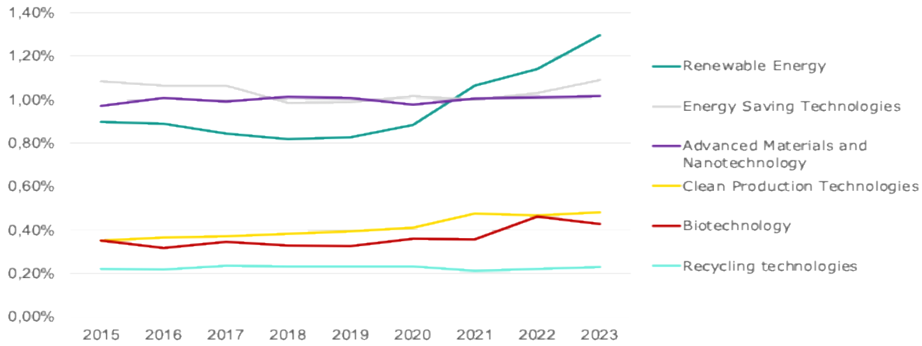
This subsection presents product-level data from Eurostat's Prodcom[10] database and trade data from UNCOMTRADE. The data enable an assessment of the EU's capacity to produce advanced technologies and provide insights into the EU's performance in translating research into technology-based products. The data also help identify potential opportunities for the EU to leverage its production capacity of advanced technologies to boost the competitiveness of its industry.

Across the EU, in 2023, green technology-based goods represented around 4.5% of the EU's total production of manufactured goods, up from 3.9% in 2012.

Key green technologies for the production of technology-based products in 2023 included renewable energy technologies, energy-saving technologies and advanced materials. Renewable energy technologies have seen a **particularly strong increase** since 2020.

Figure 9: Share of green technologies in total EU production, 2015-2023

[10] 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 Harmonised System (HS) or the Combined Nomenclature (CN), which enables comparisons to be made between production and trade statistics. The data covers only manufacturing, not services.

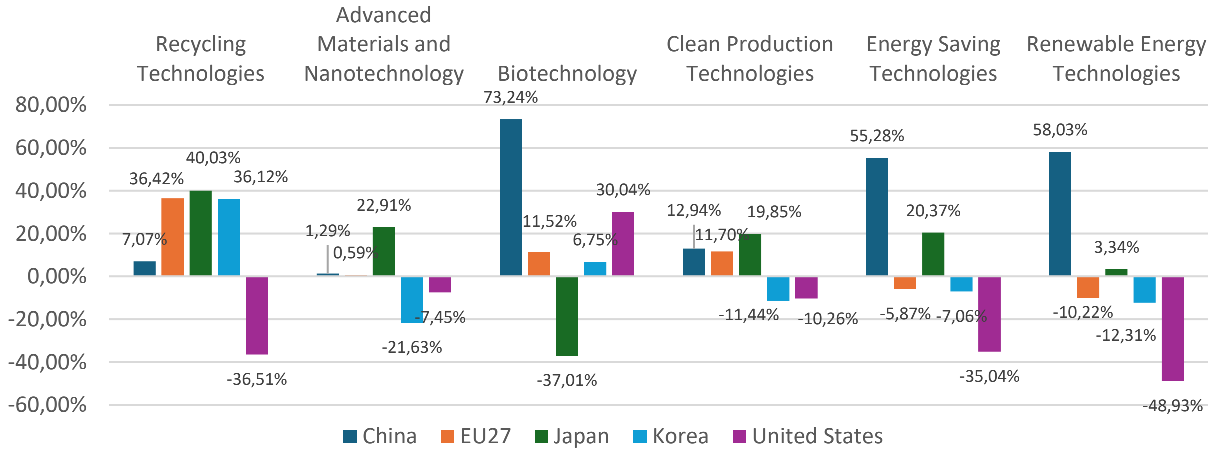


Source: IDEA Consult based on Eurostat [prom] for the European Monitor of Industrial Ecosystems (EMI)

The **EU's trade balance in green technologies has fallen steadily** from a trade surplus of around 7% in 2012 to a trade deficit of around 3% in 2022.[11] Figure 7 shows that in 2022, the EU was a net exporter in recycling technologies, biotechnology and clean production technologies. From 2012-2022, with the strong increase of Chinese exports, the EU **went from being a net exporter to a moderate net importer of renewable energy technologies and energy-saving technologies**. **The net importer status on renewable energy is largely due to photovoltaic, which overshadows a more positive though also declining status in other technologies such as wind.**

Over the same period, China improved its trade balance by approximately 40% in renewables and around 30% in energy-saving technologies. Despite being a net exporter of biotechnologies, the EU is being outpaced by both the US and more significantly by China in this domain.

Figure 10: Trade balance as a share of overall trade volume in 2022 for green technologies: comparison between EU-27, China, USA, Japan and South Korea



Source: Fraunhofer ISI, based on EPO PATSTAT for the European Monitor of Industrial Ecosystems (EMI)
Note: 2021 data for green technologies defined based on CPC Y-classes remain estimates

Some graphs (and opportunities) can be identified when comparing production and trade data with the findings of Section 2.1.1. on the adoption of green technologies by EU companies. The adoption rate of **recycling technologies** is relatively high, reaching 50% in most industrial ecosystems, in particular in energy-intensive-industries.

[11] https://monitor-industrial-ecosystems.ec.europa.eu/about/monitoring-frameworkrade

However, production data show that recycling technologies represent only around 0.2% of EU production, with the share having plateaued over the period 2015-2023. This is compounded by the fact that the EU's trade surplus in this area has fallen steadily since 2012. There is therefore an opportunity to scale up the production of recycling technologies and slow the fall in the trade surplus.

2.2 Framework conditions for the green transition

- The ecosystems receiving the most EU funding for the green transition were the mobility and agri-food ecosystems (ERDF funding) and agri-food (R&I-related funding).

- The data indicate a low overall demand for green transition skills and no recent changes. Only 1-2% of online job advertisements explicitly seek applicants with skills related to the green transition. The aerospace and defence, construction and electronics ecosystems have the highest share of professionals with green transition skills.

Framework conditions are the structural and institutional conditions that create an enabling environment for businesses to transition to more sustainable and environmentally friendly practices. Key components of these framework conditions include i) EU funding and ii) the availability of skills.

2.2.1. EU investment in the green transition

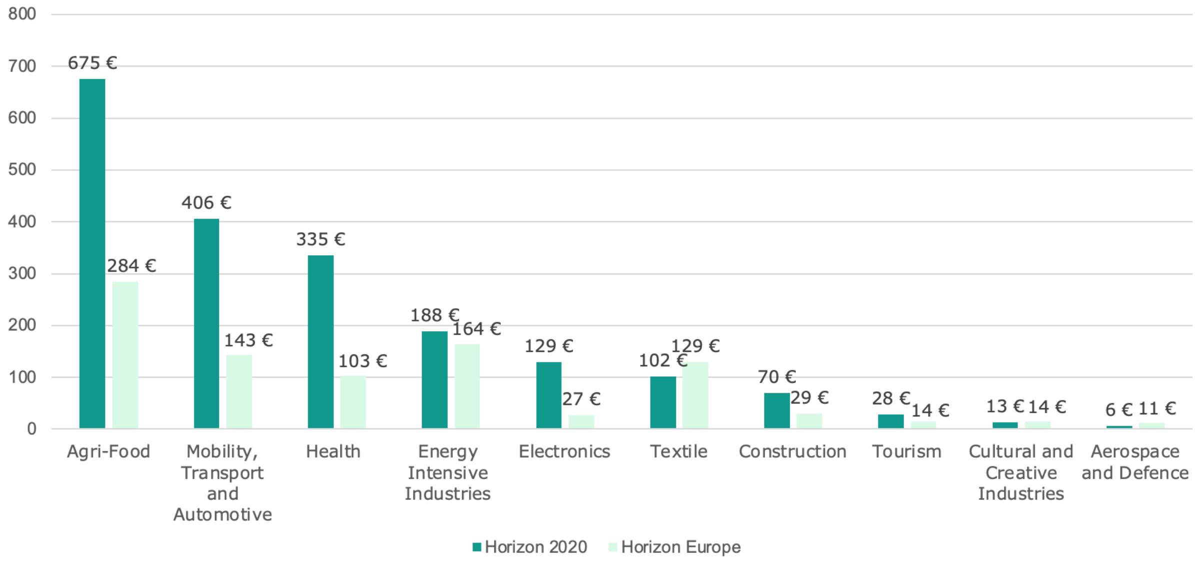
This subsection focuses on EU funding that supports EU competitiveness for the green transition in various industrial ecosystems. It analyses funding from the European Regional Development Fund and Horizon 2020/ Horizon Europe, the EU's funding programme for research and innovation. Data were collected from multiple sources, including Cohesion Open Data[12], Kohesio and the Community Research and Development Information Service (CORDIS)[13] databases.

Approximately 19% of ERDF funds allocated to industrial ecosystems were spent on projects related to the green transition. 37% (EUR 3.3 billion) of the projects co-funded by the ERDF in the mobility, transport and automotive ecosystem were allocated to support green transition projects and 34% (EUR 5.19 billion) to agri-food. Investment in agri-food reflects the sector's dual focus on sustainable practices, including environmentally friendly farming and food production.

The figure below shows the investment made using EU research and innovation funding in the green transition in each industrial ecosystem. In terms of overall EU support, **projects related to the agri-food industrial ecosystem received the highest amount (EUR 675.7 million),** and projects in the aerospace and defence the lowest (EUR 6.5 million). This can be explained partially by the fact that research and innovation in defence is also covered by other funding such as the European Defence Fund.

[12] https://monitor-industrial-ecosystems.ec.europa.eu/about/monitoring-framework
[13] https://cordis.europa.eu/

Figure 11: EU research and innovation funding for the green transition, in EUR million



Source: Technopolis Group based on Cordis for the European Monitor of Industrial Ecosystems (EMI)

2.2.2. Supply and demand for skills to support the green transition

Upskilling and reskilling are cornerstones of EU industrial policy. This subsection analyses supply and demand on the labour market in terms of green transition skills[14].

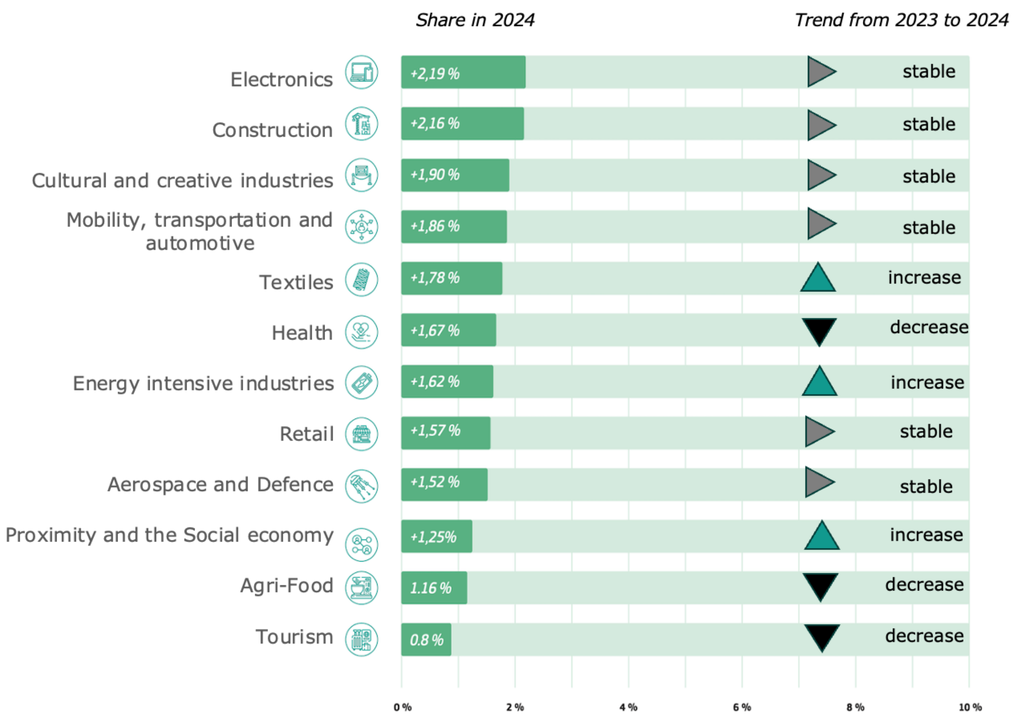
Demand for professions draws on experimental data from Eurostat/Cedefop (online job vacancies (OJA) data[15]) to provide the level of detail needed for selected technologies and industrial ecosystems at EU level[16]. In terms of the supply of professionals in the EU, the analysis draws on LinkedIn data[17] to produce a granular analysis at the level of advanced technologies and industrial ecosystems.

Only a small percentage, between 1-2% of online jobs advertisements, explicitly seek applicants with skills related to the green transition. This suggests that, although there is some demand for green skills, it is not yet mainstream, though companies often outsource these roles and rely on subcontractors to support their environmental initiatives, so the low percentage may not reflect the full extent of green-related jobs.

As the figure below indicates, the industrial ecosystems with the highest (though still low) demand for green skills have been electronics, construction and the cultural and creative industries (the latter driven by the sub-activities of architecture and design). Between 2023 and 2024, only four industrial ecosystems - textiles, energy-intensive industries, proximity and the social economy – saw increases.

[14] (Green skills related to environmental protection, the adoption of green technologies or the circular economy).
[15] https://www.cedefop.europa.eu/en/tools/skills-online-vacancies
[16] In recognition of the limitations in the availability of sufficiently granular skills data to feed into a monitor of green transition of industrial ecosystems the EMI study combines data from established secondary sources, new sources and methodologies and the enterprise survey to track the supply and demand of transition skills.
[17] Note that information provided by the LinkedIn users in their profiles is based on their self-assessment/self-evaluation.

Figure 12: Share of online job advertisements requiring green transition skills



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

The three most common new job titles relevant to the green transition suggested by an analysis of professionals active on LinkedIn and working across all industrial ecosystems include environmental engineer, sustainability manager and energy specialist.

In addition to these green skills, traditional technical skills such as combined heat and power application and materials science, have gained in prominence.

Moreover, several green transition skills stand out as relatively more important across industrial ecosystems over the period 2019-2023. These skills emphasise technical and infrastructure development needs (water systems, energy efficiency, solar energy, electric motors, energy performance of buildings); sustainable operations (transportation management, circular economy); policy and compliance (environmental policies and legislation, emission standards and the EU legislative framework); animal and ecosystem welfare (animal welfare and ecology). Together these skills account for 90% of all demand for green skills across all industrial ecosystems[18].

The average share of professionals with skills related to the green transition across all industrial ecosystems was 5.66% in 2024. **Aerospace and defence, construction and electronics are the industrial ecosystems with the highest share of professionals with green transition skills.**

The supply of green transition skills increased by an average of 2.1 percentage points from 2022 to 2024. The most significant increases were seen in the aerospace and defence, mobility, transport and automotive, and electronics ecosystems.

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

2.3 The impact of industrial ecosystems on the environment

- EU industrial ecosystems are making **uneven progress** in reducing their impact on the environment, with faster reductions made in service-based ecosystems (notably in the cultural and creative industries) than in manufacturing.

- The **health industrial ecosystem** saw the sharpest drop (of around 60%) in material extraction over the period 2017-2022, mainly due to the shift towards digitalisation and to technological advancements in pharmaceuticals and medical devices.

- The **agri-food** ecosystem has made progress in reducing emissions but increased its environmental impact in other areas, notably in terms of material extraction, blue water consumption and land use.

This section assesses the environmental impact and progress made from 2017 to 2022 by industrial ecosystems. It assesses:

i) the level of industry emissions (based on greenhouse gas emissions and particulate matter emissions);

ii) resource depletion (based on land use, material extraction and blue water consumption); and

iii) waste generation (based on damage to the environment).

The analysis is based on the European Environmental Agency's environmental indicators typology[19]. All values are reported as three-year rolling averages to capture lasting trends and the assessment of this impact is measured by Exiobase[20] [21] data. Note that the full environmental impact analysis of industrial ecosystems also includes consumption, i.e. the impact of all industry-related goods produced outside the EU but consumed within it. The focus is specifically on the change in environmental impact between 2017 and 2022 (the latest year of available data).

The results indicate that across all industrial ecosystems, service-based ecosystems[22] had a lower environmental impact than manufacturing ecosystems[23]. The best performers in services-based ecosystems are the cultural and creative industries and in manufacturing ecosystems, in health. At the other end of the spectrum, the environmental impact is highest in retail and construction.

Looking at **emissions**, the cultural and creative industries, especially traditional sectors such as publishing, printing and reproduction of recorded media, reduced their impact over the period 2017-2022 in terms of particulate matter emissions, biodiversity and greenhouse gas emissions. Part of the impact is attributable to the significant drop in 2020, possibly due to the COVID-19 pandemic, which hit this ecosystem particularly hard. The **chemical industry, part of the energy-intensive industry ecosystem,**

[19] https://www.eea.europa.eu/en/analysis/indicators

[20] Exiobase is a global, detailed Multi-Regional Environmentally Extended Supply-Use Table (MR-SUT) and Input-Output Table (MR-IOT) and combines sectoral data on a range of environmental impacts by sector with international linkages through global supply chains. EMI results were obtained by harmonising and detailing supply-use tables for a large number of countries, estimating emissions and resource extractions by industry.

[21] Since Exiobase does not have NACE codes, industrial ecosystems were directly mapped to the Exiobase sectors that align most closely with each ecosystem's activity. Typically this leads to a more conservative measure of an industrial ecosystem's environmental impact, since some economic activity is carried out in other sectors and not included. For this report, coverage is up to the year 2022.

[22] Service-based ecosystems: tourism, cultural and creative industries and retail.

[23] Manufacturing ecosystems: textiles, aerospace and defence, agri-food, construction, electronics, energy-intensive industries, health and mobility-transport-automotive.

reduced its emissions by 52% from 1990 to 2021[24], but since then the reduction seems to have stalled, stabilising at relatively high values.

In terms of **material extraction**, the **health industrial ecosystem achieved the highest reduction of over around 60% over the period 2017-2022,** mainly due to the shift to digitalisation and technological advancements in pharmaceuticals and medical devices. The ecosystem with the biggest overall impact related to material extraction is **agri-food, where there has been an 11% increase.**

The impact **of the agri-food ecosystem**[25] on **land use**[26] **increased by over 10% between 2017 and 2022**, after a period of relative stability between 2012 and 2017.

None of the industrial ecosystems reduced their blue water consumption. The biggest overall consumer of blue water in 2022 was agri-food (up 11%), followed by energy-intensive industries (up 23%).

Digital transition of industrial ecosystems

3.1. Industry efforts to digitalise

- 2023 witnessed a leap forward in the rate of adoption of several advanced digital technologies, notably in aerospace and defence, electronics, and the cultural and creative industries. Cloud technologies are the most widely adopted technology across all ecosystems, followed by artificial intelligence and the internet of things.

- Investment in digital technologies remains low, though higher than for green technologies. Nearly half of businesses allocate less than 1% of their annual turnover to advanced digital technologies, with robotics being a notable exception**.**

- Overall, the number of digital tech start-ups increased significantly in 2023. The share of advanced digital tech start-ups is higher in service ecosystems than in manufacturing industries.

-The **EU has a share of about 20.5% in global digital patent applications, roughly on par with other global players but on a downward trend.** Europe has maintained its leadership in terms of patenting in advanced manufacturing.

- Across the EU-27, digital technology-based goods accounted for 4.83% of total EU production in 2023, up from 3.75% in 2012. The strongest increase was in micro- and nanoelectronics and in photonics.

This section analyses industry action on digitalisation, drawing on:

i) the uptake of digital technologies;

ii) private-sector investment in the digitalisation of industrial ecosystems;

iii) the number of industrial tech start-ups;

iv) the level of digital technology-related patents;

v) the production of digital technology-based products.

[24] CEFIC (n.d.) Environmental performance. Retrieved from: https://cefic.org/a-pillar-of-the-european-economy/facts-and-figures-of-the-european-chemical-industry/environmental-performance/.

[25] (The only ecosystem with a significant direct impact in this dimension).

[26] (For crops, forestry and pasture).

3.1.1. Adoption of digital technologies

This section presents the results on the rate of adoption of digital technologies from the EMI enterprise survey conducted over the period from July to September 2024 with 4 000 respondents. The figures on business uptake of digital technologies gives a snapshot of how the European economy is transforming in a broad sense.

2023 witnessed a leap forward in the adoption of several advanced digital technologies. Results show that **cloud technologies** are the most widely adopted technologies across all ecosystems, closely followed by **artificial intelligence** (AI), which has recently seen significant growth in the adoption rate in some ecosystems. The adoption rate of connected devices (**internet of things**) also increased notably, although it is more specific to certain ecosystems such as electronics, aerospace, defence and health.

The industrial ecosystems that made the **most overall progress since last year in adopting digital technologies include aerospace and defence, electronics and the cultural and creative industries**, all of which saw an increase of over 10 percentage points.

Figure 13: Adoption rate of digital technologies by industrial ecosystem

	Artificial Intelligence	IoT	Cloud	Robotics	Big data	AVR	Blockchain	Edge computing
Aerospace & Defence	30.82%	21.38%	14.04%	6.72%	9.83%	8.06%	2.93%	3.84%
Agri-Food	11.03%	13.80%	10.57%	8.69%	-4.34%	-4.02%	2.47%	2.78%
Construction	28.27%	12.97%	24.79%	1.36%	5.05%	6.39%	0.35%	6.62%
Cultural & creative industry	6.17%	10.77%	10.75%	3.96%	0.68%	3.09%	0.15%	-2.39%
Electronics	31.43%	34.72%	26.89%	4.98%	11.43%	-0.06%	0.59%	10.53%
Energy intensive industry	13.06%	15.72%	8.09%	9.32%	2.24%	-2.29%	2.84%	-2.54%
Health	20.68%	10.85%	22.13%	1.45%	3.45%	-5.07%	4.79%	8.42%
Mobility Transport & Automotive	9.06%	24.79%	17.83%	6.85%	8.28%	-5.05%	1.79%	-0.79%
Retail	10.10%	6.30%	11.39%	4.21%	1.19%	-1.98%	-0.53%	4.29%
Proximity, Social economy & Civil Security	11.71%	0.04%	26.60%	3.10%	2.37%	-0.97%	0.00%	1.87%
Textile	17.74%	6.79%	0.42%	0.41%	0.12%	-3.05%	3.16%	5.94%
Tourism	14.94%	9.86%	12.46%	0.94%	0.00%	4.06%	4.22%	4.37%

Source: EMI enterprise survey 2024

3.1.2. Private-sector investment in the digital transition

The EMI study monitors private-sector investment made by industrial ecosystems and all business sizes in advanced digital technologies. It uses self-reported data on investment collected through EMI's annual enterprise survey. An analysis of the funds raised through equity and venture capital investments from 2015 to 2023 were obtained from Crunchbase data. The aim of this research is to help monitor the scale and nature of investment in advanced digital technologies in the EU-27 and across the industrial ecosystems.

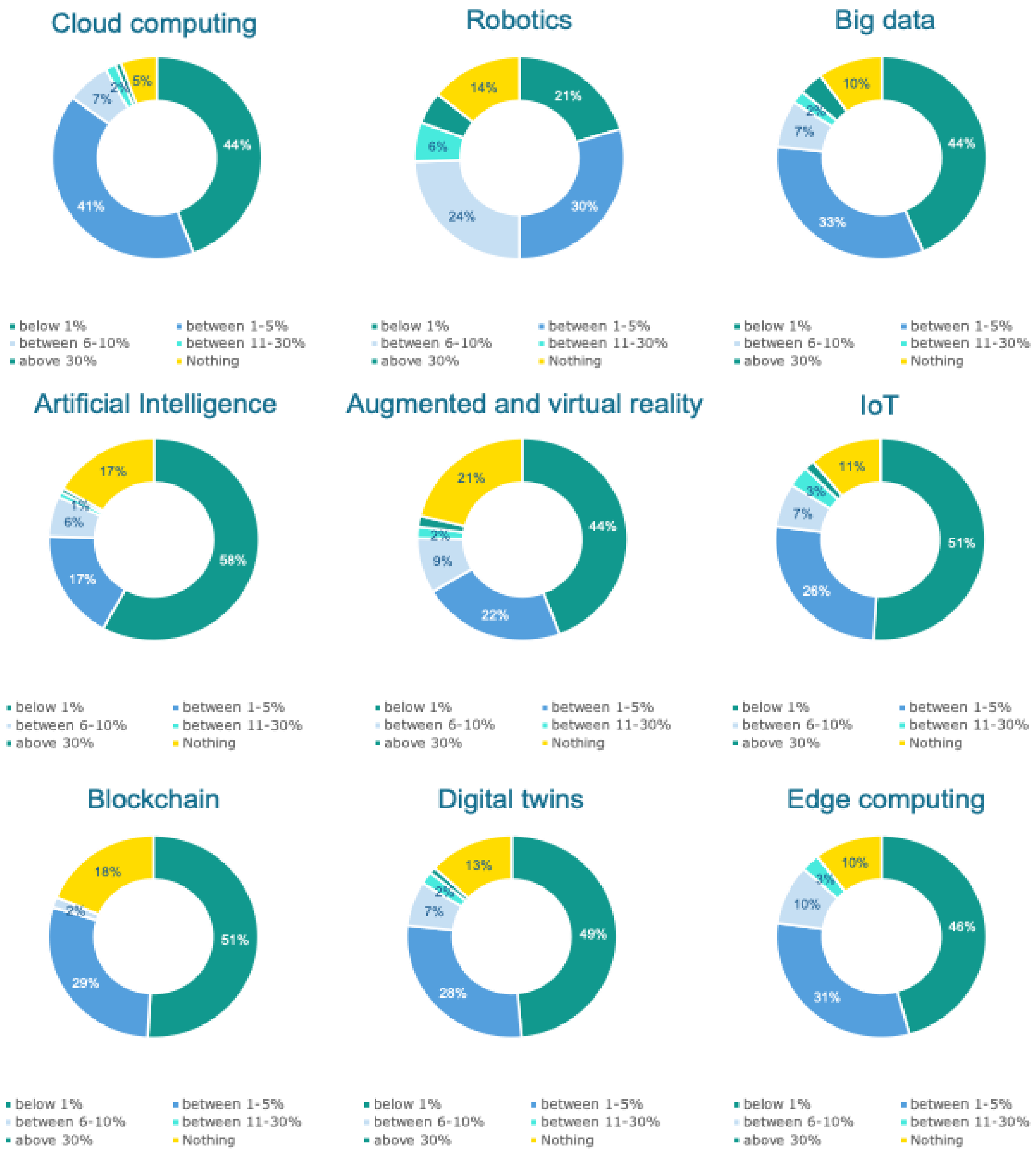
The level of private-sector investment in digital technologies is relatively low but still higher than for green technologies. Overall, 47% of businesses invest less than 1% of their annual turnover in advanced digital technologies. Some 30% of companies invest between 1-5% of their turnover. Together, these figures reflect a small to moderate level of business investment in advanced digital technologies.

Investments are focused in relatively more mature digital technologies such as cloud computing (EUR 137 billion), big data (EUR 90 billion) and IoT (EUR 85 billion), which are enablers of other newer digital technologies. However, the **technologies that have seen a higher increase of investments are notably robotics and cloud computing**.

In the specific case of SMEs, robotics is also the technology in which multiple industrial ecosystems (10 out of 12) invest over 5% of their annual turnover. Annual business investment in cloud computing is estimated at EUR 136.56 billion in total, making **cloud computing the technology with the highest overall investment of all advanced digital technologies** analysed in the EMI project.

When zooming into individual industrial ecosystems, business investment in digital technologies may well exceed 5% of turnover. For instance, the electronics industrial ecosystem stands out for the high level of investment in cloud computing (23.19%), edge computing (22.73%), robotics (19.05%), IoT (12.28%) and big data (5.88%).

Figure 14: SME investment in advanced digital technology by type of technology

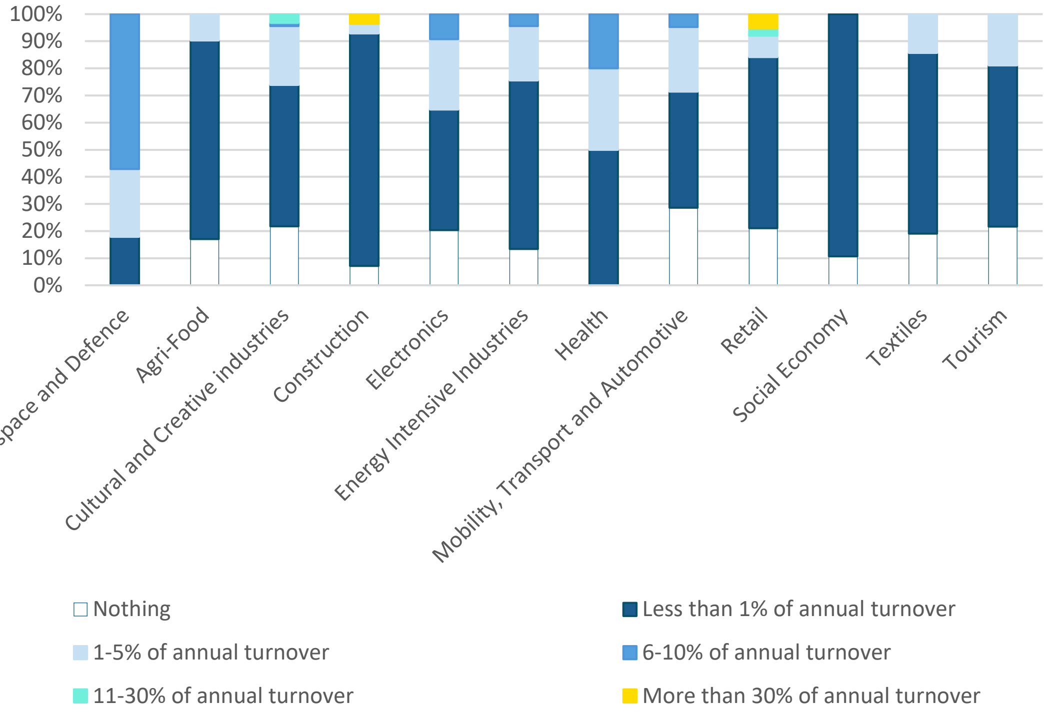


Source: Enterprise survey (2024) for the European Monitor of Industrial Ecosystems (2024)

There is a discrepancy between the uptake of and investments in AI, indicating potential dependencies. As outlined in the previous section, there is a significant increase in the adoption rate of AI. At the same time, 59% of businesses reported investing less than 1% of their annual turnover in AI.

AI is still evolving, and investing in the development of proprietary AI systems is often seen as risky, particularly for SMEs. AI investments are the fifth highest among the nine digital technologies monitored under EMI and estimated at approximately EUR 75 billion. Investments in AI are particularly pronounced in retail and construction. However, there is an increasing availability of AI-based tools without the need for large-scale investments. These tools are typically more affordable and user-friendly, making them comparatively more accessible than other advanced digital technologies to companies of various sizes.

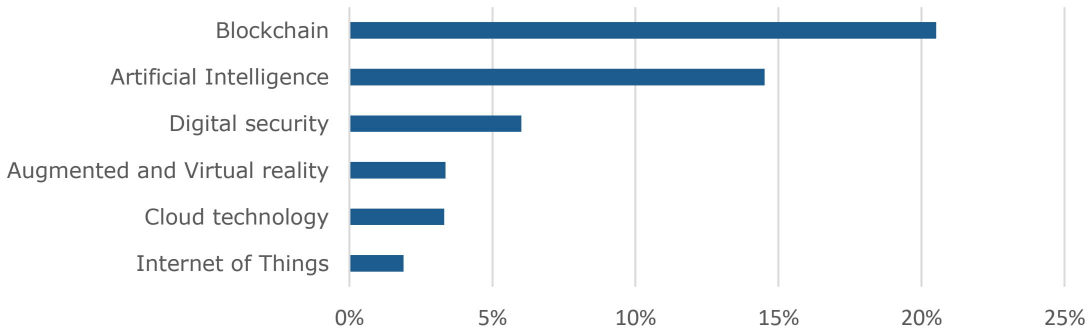
Figure 15: Investment in advanced digital technologies by industrial ecosystem, specifically in Artificial Intelligence



Source: Enterprise survey (2024) for the European Monitor of Industrial Ecosystems (EMI)

In the EU, access to venture capital for digital technologies has historically been lower than in the US. An analysis using Crunchbase data for 2015-2023 indicates that the gap between the EU and US is especially wide in technologies such as blockchain and AI. However, the venture capital gap with cloud technology and IoT is closing.

Figure 16: Average annual growth in the EU–US venture capital gap for digital technologies (2015-2023)



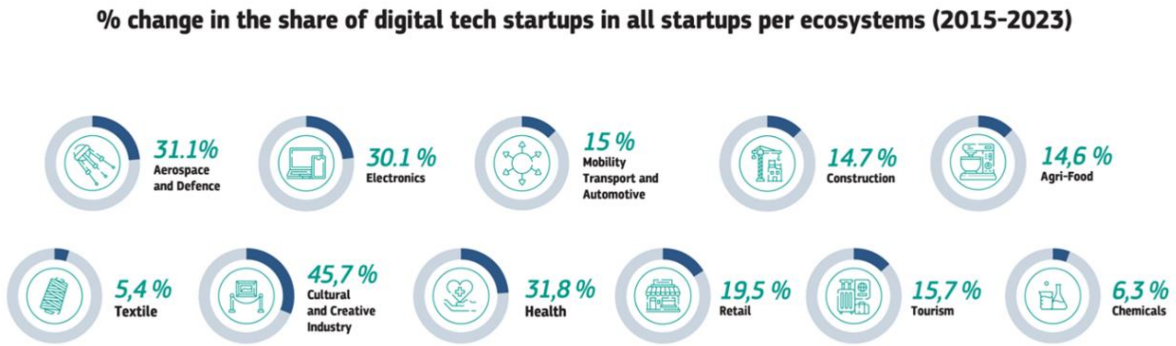
Source: Calculations based on Crunchbase for the European Monitor of Industrial Ecosystems (EMI)

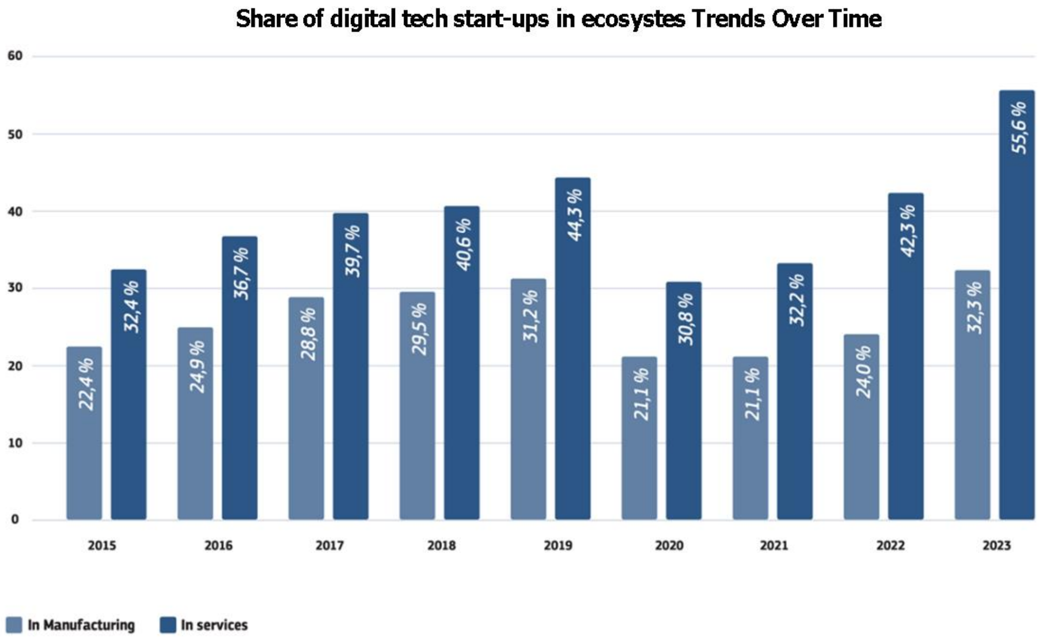
3.1.3. The digital tech start-up ecosystem

Digital tech start-ups are driving change in specific industries by developing tailored solutions to meet unique challenges and to boost efficiency. By customising technologies, these start-ups enable businesses to streamline operations and adapt to today's demands. In **health**, for instance, start-ups use AI to develop AI-driven diagnostic tools, while in **agri-food**, technology is used to create precision farming technologies. They also leverage advanced data analytics and machine learning to interpret industry-specific data, such as consumer behaviour insights in the **retail industry**.

Overall, there has been a significant increase in the share of tech start-ups. According to Crunchbase, advanced digital tech start-ups accounted for a **higher share in service ecosystems than in manufacturing industries over the 2015-2023 period**. The highest increase in digital tech start-ups over the period 2015-2023 has been in the **cultural and creative industries** (45.7%), followed by (in manufacturing) health (31.8%), aerospace and defence (31.1%) and electronics (30.1%) (see Figure 18 below).

Figure 17: Advanced digital tech start-ups supporting industrial ecosystems





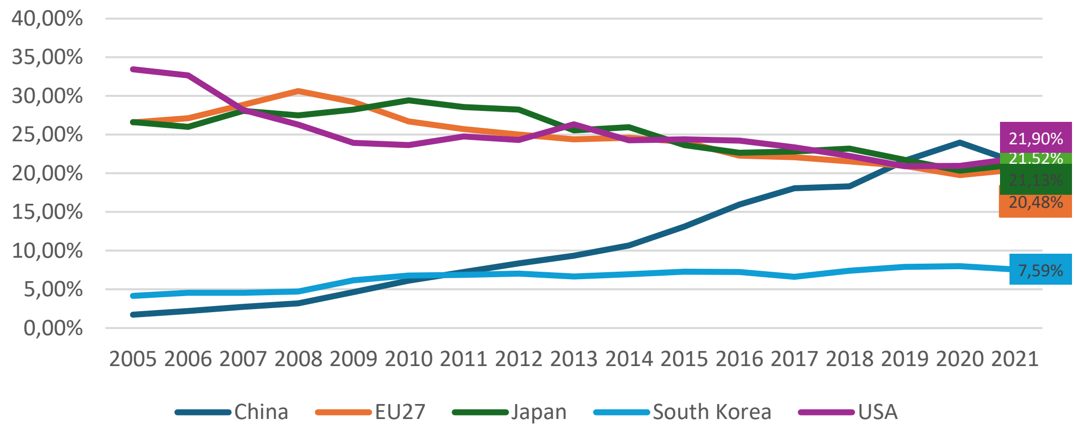
Source: Technopolis Group based on Crunchbase for the European Monitor of Industrial Ecosystems (EMI)

3.1.4. Digital technology-related patents

As in the previous chapter, this section examines transnational patent data provided by the EPO's Worldwide Patent Statistical Database[27].

In terms of patents in the digital domain, in 2021, the EU had a share of about 20.5% of patents worldwide, down from 26.5% in 2005 and about 24% in the mid-2010s. The EU's competitiveness in technology generation remains on par with China, Japan and the United States. That said, growth dynamics in the EU, the US and Japan have been much slower than the growth seen in China or South Korea. China had already reached a share of 24% of patents worldwide in 2020.

Figure 18: World share of applications for patents in digital technologies



Source: Fraunhofer ISI, based on EPO PATSTAT for the European Monitor of Industrial Ecosystems (EMI)
Note: 2021 data for green technologies defined based on CPC Y-classes are estimates

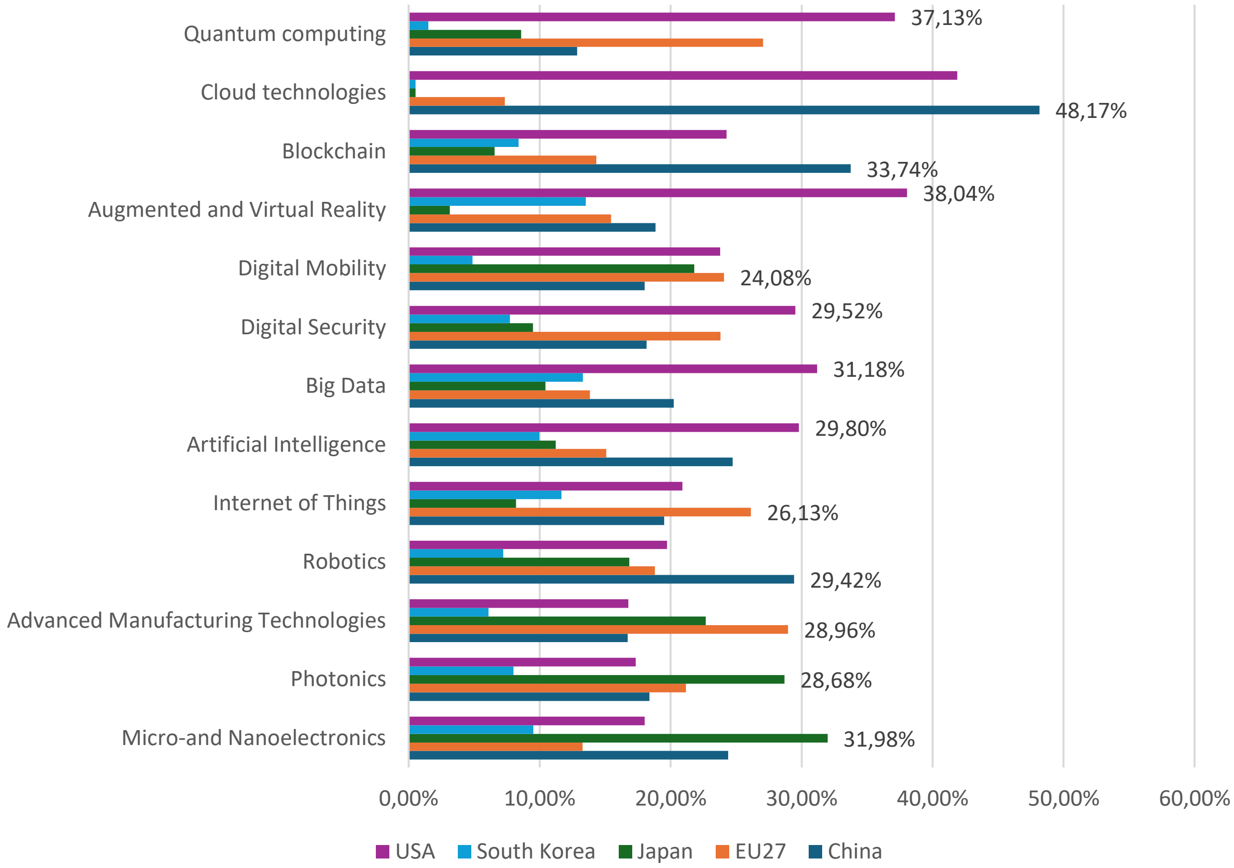
Europe has maintained its leadership in terms of patenting in advanced manufacturing, with a global share of around 28% in 2021, though this is around 12 percentage points below the share in 2005. However, in **robotics**, which used to be the second strongest field for the EU in terms of global patent share, the EU has lost almost 45% of its global share, with China now filing a considerably higher share of global patents. On the upside, with 26.13%, the EU leads in the share of **internet of things**-related patents. On **quantum computing**, the EU ranks second, though its global share of patents is 10 percentage points lower than the US share.

By contrast, the EU has a comparatively minor share of patents in augmented and virtual reality, AI, blockchain, big data, micro and nanoelectronics and, in particular, **cloud computing** (its weakest technology field, with a share of only 7.3%). There is a significant gap between the EU's share of AI patents and the share held by China and the US – in fact, the EU's share of AI patents is about half that of the US.

It is also worth noting that, on digital technology, in contrast with patents for green technology, the US stands out as being highly competitive across the board. The US often leads by a significant margin on this front, particularly in the fields of quantum computing, big data, augmented and virtual reality technologies.

[27] Disclaimer: note that using patent data has some drawbacks. First, some companies may pursue other strategies to market their inventions beyond patenting them. Second, the volume of transnational patents filed by each country does not necessarily indicate the quality of the patents. Nevertheless, patent data is a widely used measure to track technological development activities. 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.

Figure 19: Global share of patent applications by specific digital transition technology field



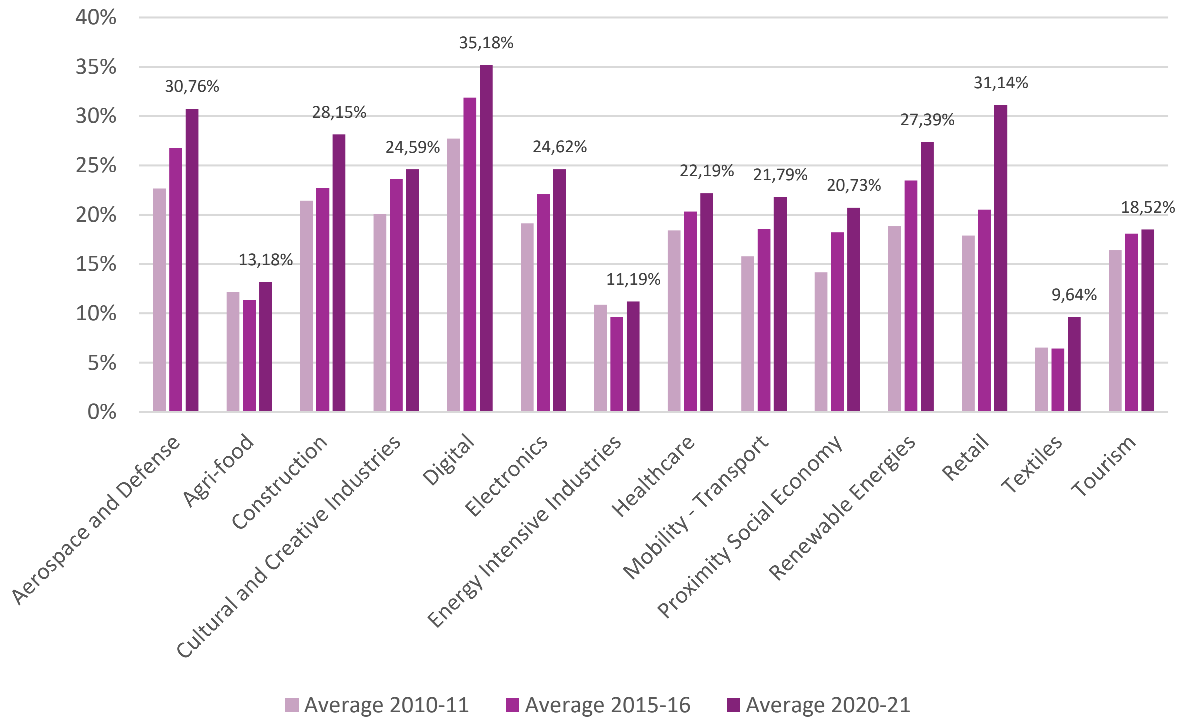
Source: Fraunhofer ISI, based on EPO PATSTAT for the European Monitor of Industrial Ecosystems (EMI)
Note: 2021 data for green technologies defined based on CPC Y-classes are estimates

Although the EU's global patent share in digital technologies has fallen over time, this does not necessarily signal a drop in the absolute number of patents filed by the EU in digital technologies. In fact, as illustrated by Figure 23, the **last decade has seen a significant,** and in most cases, continuous **increase in the share of digital patents in the patent portfolios of most industrial ecosystems.** This indicates that EU industrial ecosystems have sharpened their focus on digital innovation.

Currently, the share of digital patents in the overall patent portfolio of most industrial ecosystems is relatively high at around 20%. As to be expected, the **digital** ecosystem leads with a share of digital patents of no less than 35% in total, followed closely by the **retail and aerospace and defence ecosystems**. The industrial ecosystems with the lowest shares of digital patents in their overall patent portfolios are textiles, agri-food and energy-intensive industries[28]. Increasingly, the **highest increases** were achieved not in the digital or electronics ecosystem but in the **retail and the renewable energies ecosystems.**

Figure 20: Share of 'digital patents in overall patent portfolio by ecosystem

[28] One important observation is that digital farming technologies are not being developed in the core agri-food industrial ecosystem but instead provided mainly by suppliers in other ecosystems. The same appears to be true for internet of things technologies used in the textiles ecosystem and for advanced control technologies used in manufacturing in energy-intensive industries.



Source: Fraunhofer ISI Analysis based on EPO PATSTAT and Moody's ORBIS for the European Monitor of Industrial Ecosystems (EMI)

3.1.5. Digital technology production

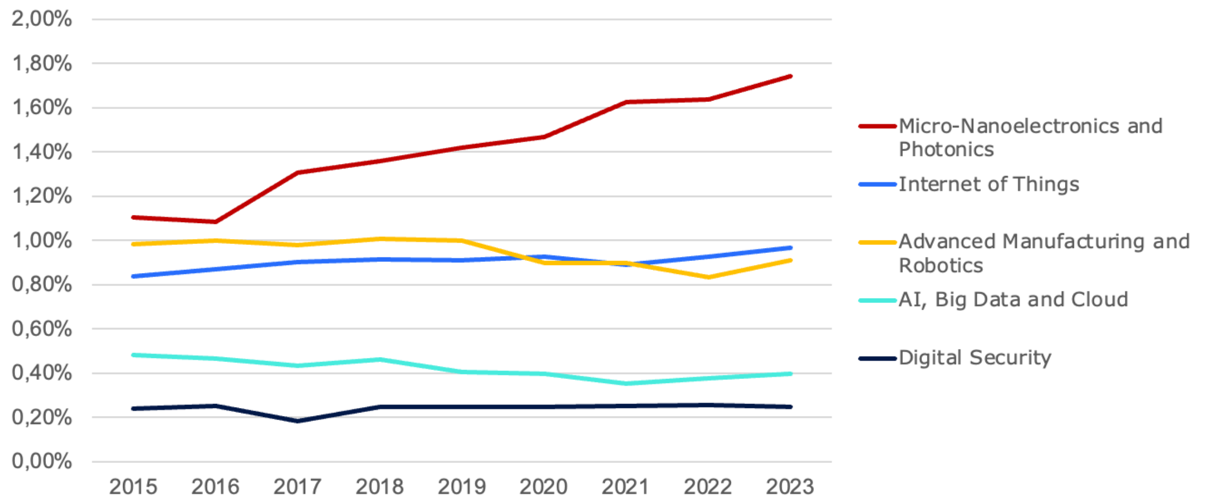
As in the previous chapter, production and trade data were used to capture the EU's capacity to produce goods directly based on advanced digital technologies.

Across the EU-27, digital technology-based goods accounted for 4.83% of total EU production in 2023, up only slightly from 3.75% in 2012. **Micro- and nano-electronics and photonics** achieved a particularly strong increase from 2020 onwards[29].

By contrast, in terms of trade, in 2022, the EU recorded a trade deficit of almost 4% in digital technologies overall. As Figure 21 below illustrates, the EU was a **net exporter** only in **advanced manufacturing and robotics technologies and recorded a trade deficit in all other digital technology fields**. Even in this domain, the EU's trade surplus has fallen over time, while China's trade balance has progressively improved from running a trade deficit of roughly 44% in 2012 to just under 6.5% in 2022, suggesting an increasing level of self-sufficiency. The largest trade deficit for the EU is in digital security, which has worsened over time.

Figure 21: Weight of production of digital technologies in total EU production between 2015-2023

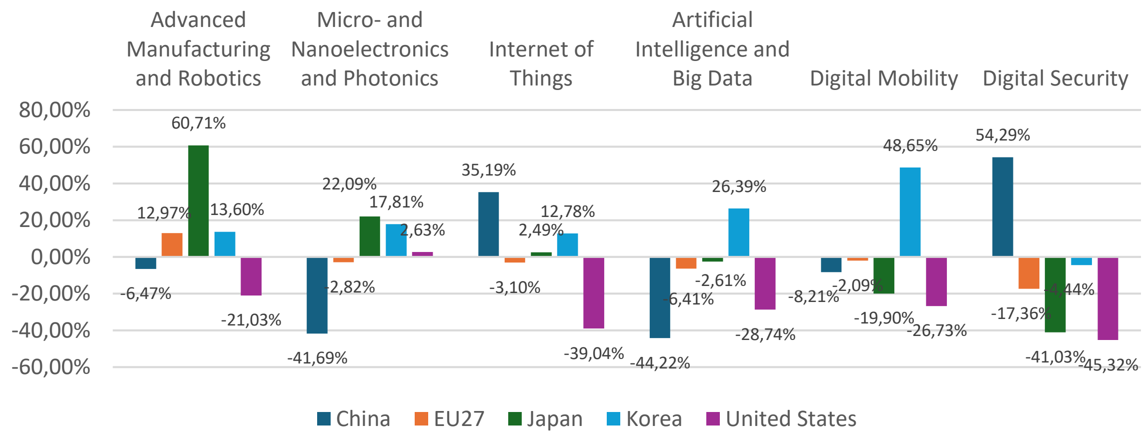
[29] The EU also produces other digital technologies, but for the sake of visual clarity, Figure 20 shows only the main technologies that make a sufficient contribution to overall EU production.



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

However, it is worth noting that the EU's trade deficit in **digital mobility** improved by around 7 percentage points from 2021 to 2022. Of all four economies analysed, only South Korea is a net exporter, standing out as highly competitive in this field, specifically in artificial intelligence and in big data.

Figure 22: Trade balance in relation to overall trade volume in 2022 for digital technologies: comparison between EU-27, China, USA, Japan and South Korea



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

When comparing the results shown above on production and trade data with the results in Section 3.2.1 on the adoption of digital technologies and the results on patent applications in Section 3.3.1, one can make the following observations. The EU's competitiveness **and progress in the field of artificial intelligence** (as measured by production, trade and patent data) **does not seem to be linked to demand trends**, as demonstrated by the change in adoption rates displayed in Figure 14.

In addition, there is a clear **gap between the EU's share of global patents in cloud technologies**, particularly compared with the US and China, and the **increasingly high rate of adoption and investment** in these technologies by EU companies. This suggests that EU companies may be mainly adopting or investing in cloud technologies that have been patented by non-EU companies. This is aligned with the fact that the cloud computing market is dominated by non-EU cloud service providers.

Therefore, on both artificial intelligence and cloud computing, the EU has an **opportunity to capitalise on the high level of demand in its domestic market to boost its own competitiveness in these fields.**

3.2. Framework conditions for the digital transition

- In terms of EU funding for the digital transition, the electronics sector received the most ERDF funding, while the health sector attracted most research and innovation-related funding.

- The **share of professionals with advanced digital skills increased significantly between 2022 and 2024, reaching 18.2%-20.9% across ecosystems in 2024**. The highest increase is in the health, electronics, and aerospace and defence ecosystems.

This section analyses the framework conditions needed to support EU competitiveness, based on two main indicators: i) EU funding and ii) skills.

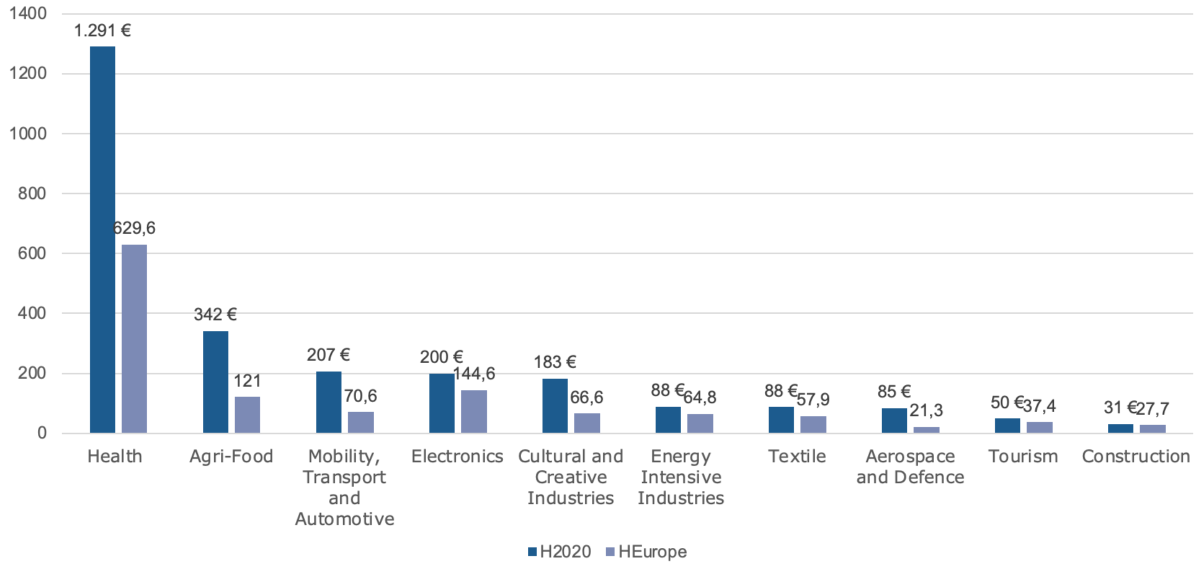
3.2.1. Public investment

This section analyses the level of EU funding for the digital transition across industrial ecosystems. It looks at funding from the European Regional Development Fund, the Cohesion Funds[30], and the EU's framework programme for research and innovation (Horizon 2020 and Horizon Europe). Data has been collected from multiple sources, including Cohesion Open Data, Kohesio, and the Community Research and Development Information Service (CORDIS) databases. The data analysis shows that:

- The **electronics** ecosystem accounts for **52.6% of the ERDF co-funding allocated to digital transition**, the highest of all ecosystems, in part due to the nature of this industry, which is closely related to digitalisation. EUR 2.7 billion was invested in projects with a digital component.
- The next highest share of funding was allocated to the health, retail and the cultural and creative industries, with 28%, 15% and 15% respectively for the digital transition.

Figure 23 shows the share of EU research and innovation funding for the digital transition in each ecosystem. In total, EUR 2.5 billion was spent on the digital transition of industrial ecosystems from Horizon 2020 and so far EUR 1.2 billion from Horizon Europe. **In total, the health ecosystem received the most EU research and innovation funding for the digital transition and the construction ecosystem received the least funding.**

Figure 23: Share of EU research and innovation funding for the digital transition in EUR million (Horizon Europe fundings covers only the period 2021- Nov 2024)



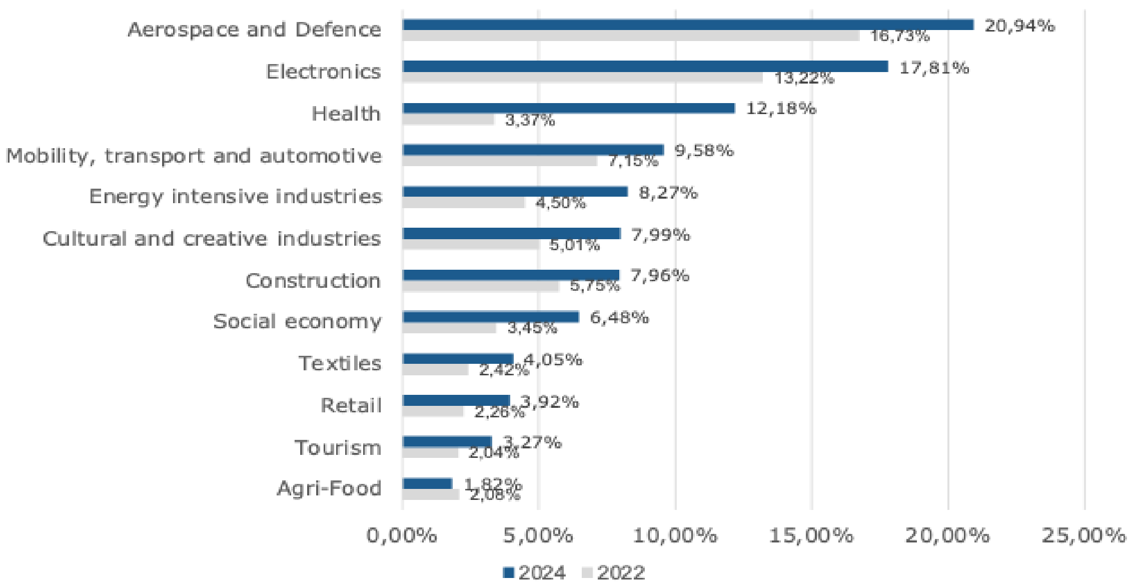
Source: Technopolis Group based on Cordis for the European Monitor of Industrial Ecosystems (EMI)

3.2.2. Supply and demand for advanced digital skills

As in the previous chapter, this section presents the analysis of data on the supply and demand of professionals with digital transition skills based on Eurostat/Cedefop data.

The **share of professionals with advanced digital skills increased between 2022 and 2024**, reaching between 18.2% (in agri-food) and 20.9% (in aerospace and defence) across ecosystems in 2024. The highest increase was in **health (9%), electronics (5%) and in aerospace and defence (4%).**

Figure 24: Change in the share of professionals with advanced digital skills across industrial ecosystems

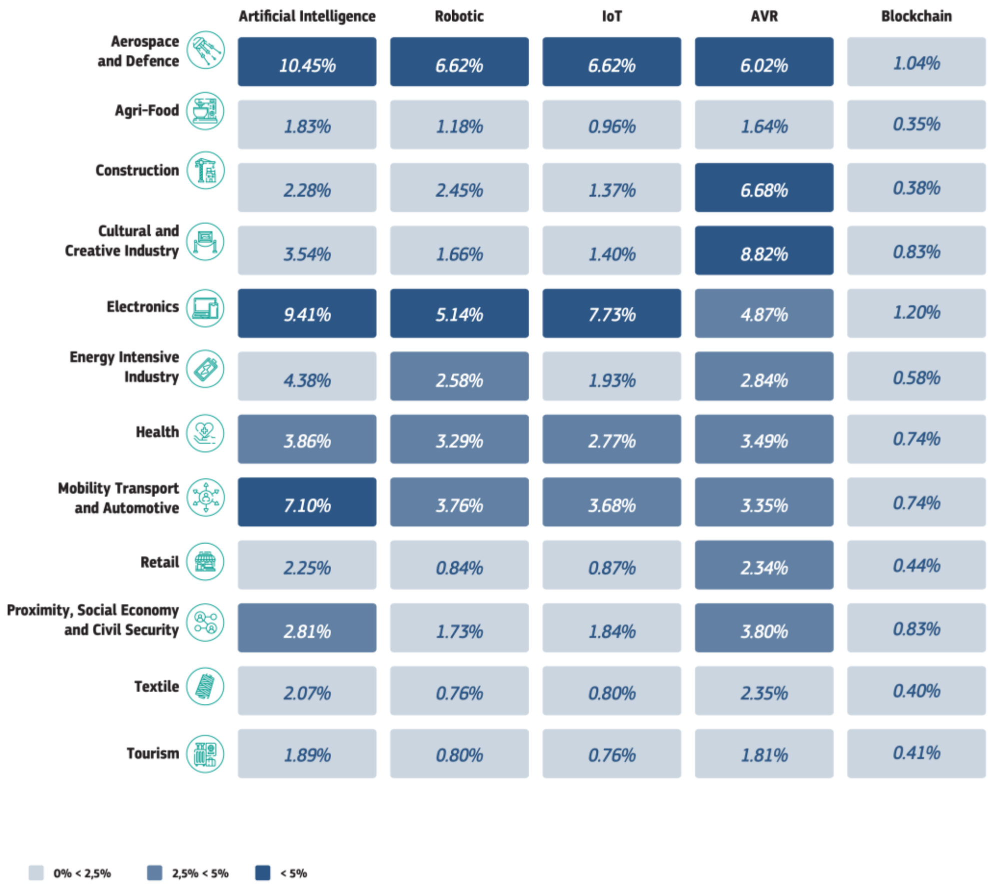


Source: Technopolis Group based on LinkedIn for the European Monitor of Industrial Ecosystems (EMI)

The share of professionals with specific advanced digital technology skills (based on LinkedIn data) indicates that most professionals with **artificial intelligence-**related skills work in the **aerospace and defence, electronics, and mobility, transport and automotive industrial ecosystems**. The highest number of professionals in the

electronics ecosystem work on internet of things technology, whereas in the **cultural and creative industries,** the focus is on professionals with experience in augmented and virtual reality.

Figure 25: Share of professionals with advanced digital skills across industrial ecosystems



Source: Technopolis Group based on LinkedIn for the European Monitor of Industrial Ecosystems (EMI)

Demand for advanced digital skills remains high across all industrial ecosystems. This is especially true for AI-skilled professionals, reflecting the rapid integration of artificial intelligence across sectors. The **highest demand for professionals with advanced technological skills is in the cultural and creative industries, followed by electronics and construction**. **Electronics** is one of the most technology-intensive ecosystems and demand for professionals with these skills has increased by 11.6%, in particular for skills in AI, machine learning and internet of things.

3.3. The impact of digital technologies on productivity

- The **adoption of digital technologies has led to significant productivity increases over the past year**. The **health and aerospace and defence ecosystems achieved the greatest productivity gains,** with average increases of **9-11% in the course of 2023** in output per hour worked.

- Among the digital technologies driving the productivity boost, **robotics** was identified as having the **greatest impact in manufacturing** industrial ecosystems and **AI in services-based industrial ecosystems.**

The digitalisation of industry is a key driver of economic transformation and competitiveness in the EU and globally. It is fostering innovation across value chains, reshaping how products are manufactured and how services are delivered. As a result, this section examines **how effectively companies have converted advancements in digital technologies into productivity gains for their businesses**. Data collected for this section comes from the survey carried out under the EMI project[31].

The adoption of advanced digital technologies has led to an 8% increase in productivity across industrial ecosystems on average since last year, as measured by output per hour worked. The health and **aerospace and defence** ecosystems achieved the greatest productivity gains. The ecosystems that made the least gains in productivity were the **retail and the cultural and creative industries**.

The EMI industrial ecosystem reports highlight[32] that, out of the digital technologies driving this productivity boost, **robotics** (in particular smart systems) had the **greatest impact in manufacturing industrial ecosystems** (by 84% of respondents). In **services-based** industrial ecosystems, **AI** (cited by 71% of respondents), data analytics and digital platforms drove productivity gains by enhancing efficiency, customer engagement and service innovation. The adoption of digital tools across ecosystems brings various benefits, such as production optimisation, data-driven decision-making, improved working conditions and greater transparency.

Productivity gains were also substantial (around 70% of respondents) in services-based ecosystems that adopted **cloud computing**. In addition, the use of big data and the internet of things have yielded immediate productivity gains for half the companies surveyed.

Certain technologies, such as **augmented and virtual reality and blockchain, are still in development** and currently demand more investment than they yield in immediate returns. As part of the EMI enterprise survey, many companies reported that these technologies are still in the test phase, with ongoing evaluations of their potential applications and long-term benefits. While promising, these technologies require further refinement and scalability before they can yield substantial productivity or profitability gains.

Figure 26: Impact on productivity of advanced digital technologies as reported by respondents (EU-27)

	Share of companies reporting an increase	
	Manufacturing	**Services**
Robotics	**84%**	67%
Artificial Intelligence	**75%**	71%
Cloud computing	61%	**70%**
Big Data	45%	43%
Internet of Things	51%	56%
Augmented and Virtual Reality	27%	**30%**
Blockchain	7%	5%

Source: 2024 EMI Enterprise Survey for the European Monitor of Industrial Ecosystems (EMI)

[31] The EMI survey is an in-house business survey that collects data on the level of change towards the green and digital transition of European businesses across twelve industrial ecosystems. It sought opinions on related investments and expected future developments. The survey used computer-assisted telephone interviewing with an overall sample of 4 000 respondents.

[32] https://monitor-industrial-ecosystems.ec.europa.eu/industrial-ecosystems

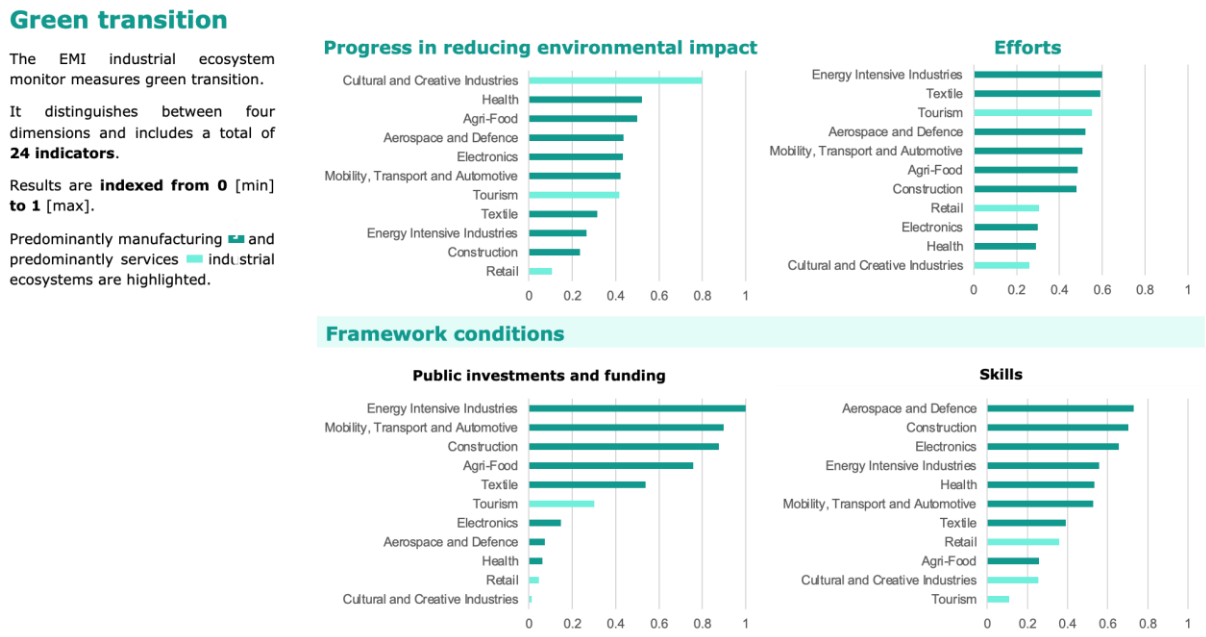
4. Industrial transition composite indicators

With the aim of identifying patterns of progress on the green and digital transitions across different ecosystems, the EMI project has developed **industrial transition composite indicators.** The indicators follow standard procedure as recommended by the JRC/OECD Handbook on Composite Indicators[33] and implemented by the COINr package[34].

The indicator framework used to build the following composite scores is based on the **37 indicators** presented in previous sections of the report, with **10 dimensions, split between the green and digital transitions** (4 each). The indicator framework is described in detail in the EMI methodological report[35] and the results are illustrated below, tracking performance, action or growth on a scale from 0 (minimum) to 1 (maximum)[36].

4.1. Progress on the green transition to support sustainable competitiveness

Figure 27: Green transition composite indicators



Source: Technopolis Group for the European Monitor of Industrial Ecosystems (EMI)

Efforts

The main types of **effort** companies make to reduce their environmental impact are grouped by several actions namely: the adoption of green technologies and environmental measures, private-sector investment, technology generation based on patents, and increasing the production of green technology. This group of composite scores tracks progress on the green transition by assessing the current state of play; not over time.

[33] https://monitor-industrial-ecosystems.ec.europa.eu/industrial-ecosystemse Indicators
[34] https://monitor-industrial-ecosystems.ec.europa.eu/industrial-ecosystems
[35] https://monitor-industrial-ecosystems.ec.europa.eu/industrial-ecosystems
[36] Proximity and the social economy were subtracted from the composite indicators analysis due to a lack of data.

Overall, **energy-intensive industries** is the ecosystem that recorded the greatest efforts to reduce their environmental impact, particularly due to the outstanding level of green technology generation. **The textiles industry** also made great efforts, mainly on high levels of technology adoption and environmental measures taken. **The tourism industry**, which ranks third, has made particular efforts on waste management, circularity and resource efficiency. However, tourism recorded very low levels of technology adoption, private-sector investment in environmental technologies and green tech start-ups. Despite the importance of private-sector investments in environmental technologies to support the green transition, the turnover allocated to adopting green technologies and the level of venture capital investments are low compared with other actions on the green transition.

Framework conditions

Framework conditions contribute to EU competitiveness, sustainable development and encourage growth. To help create the framework conditions, two factors are needed: EU funding and skills.

EU funding for the green transition is higher in manufacturing industrial ecosystems than in service-based ecosystems. **Energy-intensive industries** receive the most funds from ERDF and the **health** ecosystem receives the most from the research and innovation fund. The composite result includes other indicators in the calculation, which results in the **aerospace and defence** ecosystem recording the highest overall level of EU funding. By contrast, service-based industrial ecosystems such as retail and the cultural and creative industries record low levels of green public investment, resulting in a performance of below 0.1.

In terms of **green skills**, most industrial ecosystems are clustered in the lower-middle range in terms of supply and demand. Only **aerospace and defence, construction and electronics** perform above the 0.6 threshold. Service-based ecosystems all perform in the lowest range, together with the **agri-food ecosystem,** with a performance below 0.4.

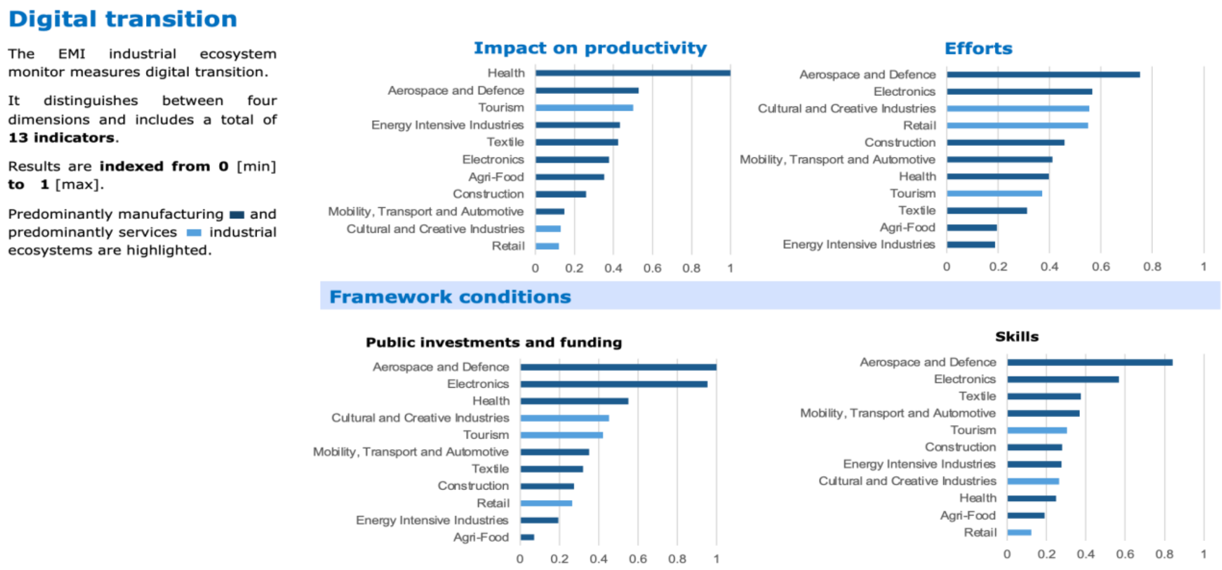
Progress to reduce environmental impact

This composite score assesses the progress made by ecosystems in reducing their environmental impact from 2017 to 2022[37]. As shown in the graph, most industrial ecosystems report mixed progress. For instance, the **cultural and creative industries** recorded the best performance, followed by **health**, driven by their significant reduction in material extraction[38]. **Agri-food** ranks third as a result of their progress in reducing water consumption over the 2017-2022 period. Despite the positive dynamics, the overall impact on the environment produced by the agri-food ecosystem is still high compared to most other ecosystems.

[37] Changes are calculated using a rolling average of the data from 2017 to 2022 and indexed to the year 2017.
[38] This example highlights an important assumption behind the results of the composites, namely that results are subject to a compensation effect during the aggregation process.

4.2. Digital transition supporting sustainable competitiveness

Figure 28: Digital transition composite scores



Source: Technopolis Group for the European Monitor of Industrial Ecosystems (EMI)

Efforts

Similarly to progress in the green transition, this chapter measures the main types of effort companies make to progress in the digital transition in several areas, namely: the adoption of digital technologies, private-sector investment, trends in digital tech start-ups, technology generation captured by patents and the creation of digital technology.

Aerospace and defence is the ecosystem that recorded the most efforts made on the digital transition due to their adoption of advanced digital technologies (AI, IoT and cloud). **Electronics** rank second, standing out for the broad-based investment (around 6-10% of annual turnover) in cloud computing, edge computing and robotics.

Technology generation for the digital transition recorded an outstanding performance in the **creative and cultural industries and in retail (ranking third and fourth)**. The industrial ecosystems with the lowest shares in digital patents among their overall patent portfolios are **agri-food and the energy-intensive industries** with a threshold below 0.2.

Framework conditions

Framework conditions to support the digital transition contribute to industrial competitiveness and encourage growth. To create the framework conditions, EU funding and skills are needed.

A moderate level of **EU funding** is allocated to digital public investments in all ecosystems, except for in **electronics,** which stand out. The **cultural and creative industries and tourism** are the best performers in the service-based ecosystems with a threshold of 0.4.

In terms of **skills,** similarly to the situation for the green transition, the share of professionals with advanced digital skills has grown in most industrial ecosystems between 2022 and 2024 though the supply remains low. **Aerospace and defence** stand out as the ecosystem with the highest level of advanced digital skills.

Impact on productivity

To track progress on the digital transition, industrial competitiveness is measured by an in-house survey assessing the change in output per hour worked related to production costs per output. The results show a moderate level of variance between ecosystems, with one industrial ecosystem standing out as a high performer, **health**. This result can be explained by the significant reduction in production costs that the health ecosystem achieved by adopting advanced digital technologies. **Aerospace and defence and tourism** are mid-level performers at around 0.5. The **cultural and creative industries and retail** recorded the lowest performance of all ecosystems, recording a very low impact on productivity.

5. Appendix

Figure 29: EMI indicator framework

Indicator label	Indicator	Source
SUSTAINABLE COMPETITIVENESS		
1.1 Progress in alleviating environmental pressure on resource consumption		
1.1.1 Material extraction	Used and unused crops and crops residue, grazing and fodder, forestry and timber, fisheries, non-metallic minerals, iron ore, non-ferrous metal ores, coal and peat, and oil and gas (G Tons) (growth - indexed to year 2017)	Exiobase
1.1.2 Blue water use	Consumption of blue water (fresh surface or groundwater) (1018 m^3) (growth - indexed to year 2017)	Exiobase
1.2 Progress in reducing environmental pressure on climate and biodiversity		
1.2.1 GHG emissions	Emissions of greenhouse gases (as defined in IPCC AR5) converted to CO_2 equivalent using the GWP100 conversion (Global Warming Potential for a 100-year time horizon) (G Tons CO_2) (growth - indexed to year 2017)	Exiobase
1.2.2 Biodiversity	Damage to the ecosystem by ecotoxic emissions (1012 PDF * m^2 * year) (growth - indexed to year 2017)	Exiobase
1.2.3 Particulate matter emissions	Particulate matter consists of a mixture of droplets smaller than 2.5 micrometres and 10 micrometres and emitted locally by various sources such as vehicle exhaust, smoke, road	Exiobase

Indicator label	Indicator	Source
	dust, vehicles and airplane tyres. The annual volume in megatonnes comes from the Exiobase 3.8.2 production-based account (growth - indexed to year 2017)	
1.3 Digital impacts		
1.3.1 Productivity gains	Digital tech-driven productivity increase (share of total SMEs - average of all technologies)	2024 EMI enterprise survey
1.3.2 Production costs	Digital tech-enabled cost reduction (share of total SMEs - average of all technologies)	2024 EMI enterprise survey
EFFORTS		
2.1 Green transition commitment		
2.1.1 Green technology adoption	Companies adopting green technologies (share of total companies)	2024 EMI enterprise survey
2.1.2 Strategy to reduce carbon footprint and become climate neutral or negative	Companies with a concrete strategy to reduce their carbon footprint and become climate neutral or negative (share of total SMEs)	2024 EMI enterprise survey
2.2 Circular economy efforts		
2.2.1 Switching to greener suppliers of materials	SMEs switching to greener suppliers of materials	Eurobarometer
2.2.2 Recycling, by reusing material or waste within the company	SMEs recycling by reusing material or waste	Eurobarometer
2.2.3 Designing products that are easier to maintain, repair or reuse	SMEs designing products that are easier to maintain	Eurobarometer
2.3 Waste management efforts		
2.3.1 Minimising waste	SMEs taking action to minimise waste	Eurobarometer
2.3.2 Selling your residues and waste to another company	SMEs selling residues and waste to another company	Eurobarometer
2.4 Resource efficiency efforts		
2.4.1 Saving water	SMEs taking action to save water (share of total SMEs)	Eurobarometer
2.4.2 Saving energy	SMEs taking action to save energy (share of total SMEs)	Eurobarometer
2.4.3 Saving materials	SMEs taking action to save material (share of total SMEs)	Eurobarometer

Indicator label	Indicator	Source
2.5 Digital transition commitment		
2.5.1 Digital technology adoption	Companies adopting digital technologies (share of total SMEs)	2024 EMI enterprise survey
2.5.2 Digital transformation strategy	Companies with a concrete strategy for digital transformation (share of total SMEs)	2024 EMI enterprise survey
2.6 Private investment in green transition		
2.6.1 VC and private equity investments in green tech	Volume of VC and private equity invested in companies generating green transition technologies (share of total VC)	Crunchbase
2.6.2 Green transition investment share	Average share of turnover invested by companies for their green transition (share of turnover)	2024 EMI enterprise survey
2.7 Private-sector investment in the digital transition		
2.7.1 VC and private equity investment in digital tech	Volume of VC and private equity invested in companies generating digital technologies (share of total VC)	Crunchbase
2.7.2 Digital transition investment share	Average share of turnover invested by companies for their digital transition (share of turnover)	2024 EMI enterprise survey
FRAMEWORK CONDITIONS		
Investment		
3.1 Investment in the green transition		
3.1.1 EU R&D funding for the green transition	EU R&D funding for green transition projects (share of value in total funding)	Cordis
3.1.2 ERDF funding for the green transition	ERDF funding for green transition projects (share of value in total ERDF funding in EUR)	Kohesio
3.2 Investment in the digital transition		
3.2.1 EU R&D funding for the digital transition	EU R&D funding for the digital transition (share of value in total funding in EUR)	Cordis
3.2.2 ERDF funding for the digital transition	ERDF funding for the digital transition (share of value in total ERDF funding in EUR)	Kohesio
Technology generation		
4. 1 Green technology generation		
4.1.1 Green transition technology generation by start-ups	Share of tech start-ups generating green transition technologies (share of start-ups)	Crunchbase

Indicator label	Indicator	Source
4.1.2 Green patents	Patent applications in green technologies (three-year averages of share of green patents in all patents filed in respective national ecosystem)	Patstat
4. 2 Digital technology generation		
4.2.1 Digital technology generation by start-ups	Number of technology start-ups generating digital transition technologies (share of start-ups)	Crunchbase
4.2.2 Digital patents	Patent applications in digital technologies (three-year averages of share of green patents in all patents filed in respective national ecosystem)	Patstat
Skills		
5.1 Green skills		
5.1.1 Green skills supply	Professionals with green transition skills employed in industrial ecosystems	LinkedIn
5.1.2 Green skills demand	Job advertisements with requirements for green transition skills per industrial ecosystem (share of total advertisements)	Cedefop Online Job Advertisement tables (OJA)
5.1.3 Green skills roles	Share of SMEs with a significant focus on jobs relevant to environment protection and environmental sustainability (between 11 and 50 employees)	2024 EMI enterprise survey
5.2 Digital skills		
5.2.1 Digital skills supply	Professionals with digital transition skills employed in industrial ecosystems (share of total professionals)	LinkedIn
5.2.2 Digital skills demand	Job advertisements with requirements for digital transition skills per industrial ecosystem (share of total advertisements)	Cedefop Online Job Advertisement tables (OJA)
5.2.3 Digital skills roles	Share of SMEs with a significant focus on digital jobs or IT-related roles (between 11 and 50 employees) (share of total SMEs)	2024 EMI enterprise survey

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