European Commission

Monitoring industrial ecosystems

ENERGY INTENSIVE INDUSTRIES

Analytical report – 2024 Edition

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TABLE OF CONTENTS

TABLE OF FIGURES

Executive Summary

This report has been prepared within the 'European Monitor of Industrial Ecosystems' (EMI) project with the objective to analysing the green and digital transformation of industrial ecosystems and progress made over time, in this specific case Energy Intensive Industries (EII).

The second edition of the Industrial Ecosystems series has divided the analysis into two sections meaning, 'green transition' and 'digital transition' followed by three subsections each showing: a) industry efforts, b) framework conditions and c) the impact on the environment and on productivity.

The key findings of this year's analysis are being presented below:

Green Transition

What progress has the industry made in taking action for the environment?

- The analysis highlights the critical role of **technology development in the green transition of Energy Intensive Industries**, as green transition-related patent applications comprised 20% to 24% of all patents filed within the EII industrial ecosystem. A notable increase during the COVID-19 pandemic is evident, underscoring the importance of fostering innovation during that period.

- In 2024, **17% of companies in the EII industrial ecosystem have adopted strategies to reduce their carbon footprint** and become climate neutral or negative, showing limited commitment.

- EII companies prioritise measures that focus on **minimising waste, with an increase from 46% in 2021 to 69% in 2024. This was followed by energy saving measures**, adopted by 57% of companies, and materials saving efforts, which were prioritised by 55% of companies. A global increase in the adoption of environmental measures from 2021 to 2024 underpins the overall prioritisation of minimising waste and enhancing resource efficiency in support of overall green transition efforts.

- **Environmental startups in the chemical subindustry predominantly lie in the area of advanced manufacturing technologies** with a total of 72 startups created between 2015 and 2023. In addition, startups also focus on recycling technologies, and to a less extent, clean production technologies, renewable energy and energy saving technologies.

- The majority of EII companies invest less than 5% of annual turnover in environmental technologies and measures. A third of all companies and over 50% of high-emitting businesses reported access to capital as a major obstacle. Following the results from the Eurobarometer, 68% of EII companies received private funding from a bank, investment company or venture capitalist to produce green products or services, compared to 42% that received funding for enhancing resource efficiency.

- **Venture capital investments** for the chemical subindustry lie predominantly in the area of **recycling technologies** over the period 2015-2024, highlighting the relative importance of recycling technologies as a topic for young companies.

To what extent do framework conditions such as public financing and skills support the green transition?

- The EII industrial ecosystem received **EUR 10.5 bn in support from the European Regional Development Fund** for the period 2014-2020. Projects that addressed specifically the **green transition of EII accounted for EUR 2.88 bn.**

- **38% of the identified EII ERDF projects contribute to the green transition, while 10% are active in advanced green technologies,** such as energy saving technologies, advanced materials and renewable energy technologies.

- While the **Horizon 2020 programme provided EUR 302.5 m** in funding to projects within the EII industrial ecosystem, Horizon Europe has so far allocated EUR 229.2 million. Under Horizon 2020**, 62.4% of the funding to EII projects contributed to the green transition**. For Horizon Europe, **71.9% of the funding** to EII projects contributes to the green transition (for the period where data was available notably 2022-2024).

- **The EII industrial ecosystem faces a mismatch and skills gap,** while having access to a qualified workforce throughout the regions and subindustries is a prerequisite for innovation. The **chemical subindustry** faces challenges related to up-skilling, re-skilling and sufficient supply of jobs at technical level to attract and keep talents. The share of professionals registered on LinkedIn and employed in the chemical subindustry with skills relevant to the green transition attained 17.88% in 2024, up from 6.14% in 2022.

How is the industrial ecosystem's impact on the environment changing?

- The EII industrial ecosystem is traditionally known for its large environmental impact and its energy consumption. Although EIIs reduced their emissions significantly between 1990 and 2015 and continued improving thereafter, achieving climate neutrality by 2050 requires a **deeper commitment to sustainability.**

- The top four economies—Germany, France, Italy, and Spain—represent 63% of the EU's GDP and **generate more than half of the EU's greenhouse gas emissions from EII**.

- Total GHG emissions from the EU27 **chemical subindustry decreased 133 million tonnes** (CO_2) from 1990 to 2021, a decline of 52%. Nevertheless, since 2015 these emissions have **remained relatively stable** as overall production has increased over the period from 2015 to 2019, before falling again due to the COVID-19 pandemic and subsequent war in Ukraine.

- The chemical subindustry has played an important role in **strengthening energy efficiency**. In particular, improvements in energy efficiency and energy recovery in production processes have diminished the total energy consumption in the chemical and petrochemical subindustry. The EU27 energy consumption related to the chemical subindustry has **decreased with 20% since 1990**.

- The **generation of hazardous and non-hazardous waste in the EII industrial ecosystem increased** from 35.93 million tonnes in 2004 to 55.08 million tonnes in 2020. The volume of hazardous waste remains largely stable over the considered period, while the share of hazardous waste in the total waste in EU EII is decreasing.

Digital Transition

What is the progress of industrial efforts towards digitalisation?

- The share of digital related patenting activities in the EII industrial ecosystem lies **between 7 and 9%**. These relatively lower values can be explained by the fact that patents supporting the digital transition may be rather developed in other industrial ecosystems.

- **24% of companies had a concrete strategy in place for digital transformation** in the EII industrial ecosystem in 2024.

- **The EMI Enterprise Survey revealed an increase in the uptake of digital technologies like** Cloud, Internet of Things, Artificial Intelligence, and Robotics technologies. - 62% of businesses that adopted AI did so within the past three years. **20.5% of companies use AI in the marketing and sales,** followed by 17% in product/service design**.** Several AI applications are rapidly evolving in the chemical subindustry, especially in product design, more effective replacement of hazardous materials, AI-driven predictive toxicology, enhancing predictive maintenance, and optimisation in production operations and inventory decisions.

- Digital technology startups are increasingly influencing the chemical subindustry by introducing innovative solutions that **enhance efficiency, sustainability, and competitiveness**. These startups focus on various areas, including advanced chemical manufacturing, data analytics, artificial intelligence and digital platforms. Digital startups lie mainly in the area of **AI and big data** for the period 2015 to 2022.

- **The vast majority of EII companies invest less than 5% of their annual turnover into digital technologies**. Technologies attracting between 6-10% of annual turnover include AR/VR, Big data, Blockchain, IoT and AI.

To what extent do framework conditions such as public financing and skills support the digital transition?

- The analysis shows that about **11% (or EUR 1.14 bn) of the funding to EII ERDF projects** supported the digital transition. In terms of **number of ERDF projects, 16%** is contributing to the digital transition (or 1 399 projects).

- The analysis of the CORDIS data demonstrates that the Horizon 2020 programme provided EUR 302.5 million in funding to projects classified under the EII industrial ecosystem[1]. Horizon Europe thus far[2] provided EUR 229.2 million.

- In Horizon 2020, **36.7% of the funding to EII projects contributed to the digital transition**. In Horizon Europe, **28.4% of the funding** to date contributes to EII projects related to the digital transition.

- There were **2.56 million professionals registered in the chemical subindustry on LinkedIn in April 2024.** Within these registered professionals, **11.29% indicated to have one type of digital skill** in 2024, which is an increase from 2022 where **10.42%** were found to have at least one digital skill.

- The total number of **online job advertisements** in the EII industrial ecosystem **amounted to 139 863 in 2023** in the EU27. The results of the data analysis show that **12% of the job advertisements** included a requirement of **advanced digital skills such as AI, big data, augmented and virtual reality, or cloud.**

What is the progress of industrial efforts towards digitalisation?

- Digital transformation provides companies in the EII industrial ecosystem the opportunity **to improve operations by optimising logistics and processes with AI, sensors, and human-machine interfaces using AR/VR**.

- The EMI Enterprise Survey of EII companies revealed that the **adoption of advanced digital technologies has led to an increase in productivity of around 10% in 2024**. This increase in productivity can be attributed to the adoption of robotics and AI, according to respondents.

- Countries such as **Germany, France, Spain, Italy and Poland** that **promote knowledge valorisation of digital and green technologies** through strong co-location patterns also show a strong performance in the EII industrial ecosystem in terms of production, trade and patents.

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[1] The methodological report provides detailed insights into the methodology. In particular, the CORDIS data have been merged with the relevant EuroSciVoc data. EuroSciVoc connects projects to relevant scientific concepts, providing a deeper understanding of the research focus.
[2] Cut-off date is March 2024

1. Introduction

1.1. Objectives

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

The EU's updated industrial strategy[3] has identified 14 industrial ecosystems[4] – one of them being **'Energy Intensive Industries (EII)'** - that is in the focus of this report. The industrial strategy defined industrial ecosystems as encompassing all players operating in a value chain: from the smallest startups to the largest companies, from academia to research, service providers to suppliers. The notion of ecosystems captures the complex set of interlinkages and interdependencies among sectors and firms across the EU. Industrial transition is driven by technological, economic, and social changes, and in particular by green and digital technologies and the shift to the circular economy. The process is however characterised by complex, multi-level, and dynamic development. To make transition sustainable, technological change needs to be coupled with new business models, the necessary investments, skills, regulatory framework conditions and behavioural change across the ecosystem.

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

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

The **methodological report** that sets the conceptual basis and explains the technical details of each indicator is found in a separate document uploaded on the EMI website[5]. Moreover, some of the specific industry codes used throughout this analysis have been also included in Appendix B. The green and digital technologies considered in this study are include the following:

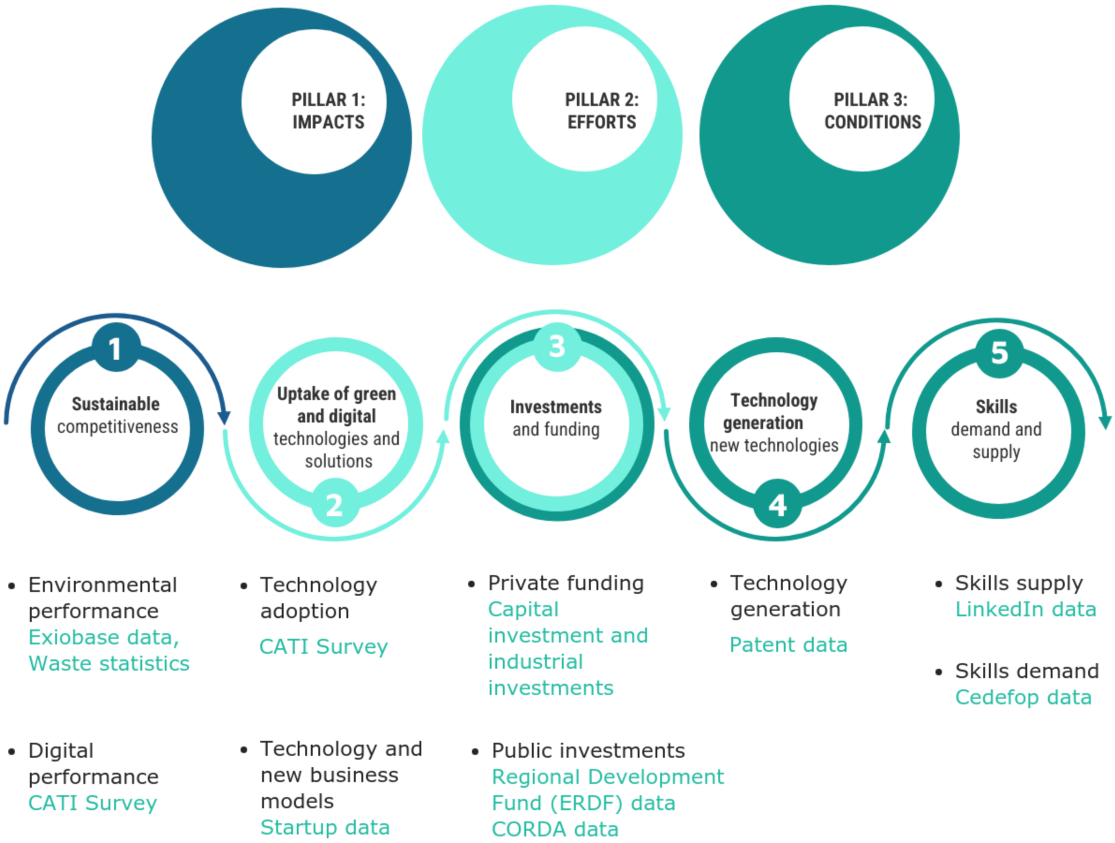
- *Green transition technologies*: advanced materials, biotechnology, clean production technologies, recycling technologies, energy saving technologies
- *Advanced digital technologies*: artificial intelligence, cloud computing, augmented and virtual reality, blockchain, robotics, Internet of Things, digital security

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

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

[5] https://monitor-industrial-ecosystems.ec.europa.eu/sites/default/files/2023-12/EMI_Updated_Monitoring framework_Final 180923.pdf

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



Source: Technopolis Group, IDEA Consult and Fraunhofer ISI

This report contributes to the analysis of the **key pillars put forward in the 'Blueprint for the development of transition pathways'[6]** of the Industrial Forum developed in 2022.

The updated EU Industrial Strategy[7] underlines a swift green and digital transition of EU industry and its ecosystems. As a result, each industrial ecosystem must transform its business models and value chains in support of a green, digital, and resilient European economy. The concrete and actionable plans to enable this transition are outlined in transition pathways. For the EII, in 2021, a staff working document (SWD) with scenarios for a transition pathway has been published[8], which served as the starting point for a consultation and co-creation process with stakeholders. Next, it was decided that the transition pathway was covered by the 'Masterplan for a competitive transformation of EU EII enabling a climate-neutral, circular economy by 2050'[9].

For some of the **subindustries of the Energy Intensive Industries (EII) industrial ecosystem,** there are specific transition pathways developed. The chemical subindustry

[6] European Commission (2020) pathways. _Blueprint for the development of transition pathways for industrial ecosystems. Retrieved from: https://ec.europa.eu/docsroom/documents/49407/attachments/1/translations/en/renditions/native
[7] European Commission (2021) COM/2021/350 final. Communication from The Commission to The European Parliament, The Council, The European Economic and Social Committee and The Committee of The Regions Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe's recovery. Retrieved from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0350
[8] European Commission (2021) Commission Staff Working Document. For a resilient, innovative, sustainable and digital energy-intensive industries ecosystem: Scenarios for a transition pathway. Retrieved from: https://ec.europa.eu/docsroom/documents/47059
[9] European Commission (2019) Masterplan for a competitive transformation of EU energy-intensive industries enabling a climate-neutral, circular economy by 2050. Retrieved from: https://data.europa.eu/doi/10.2873/854920

has published its transition pathway in 2023[10] and the European metals industry, including both ferrous and non-ferrous metals, has initiated the process to establish its own transition pathway[11]. In 2024, an annual progress report of the transition pathway for the chemical subindustry was published[12].

Furthermore, this report considers and builds upon communication, data and information from other European and international agencies, such as the European Environment Agency (EEA). It also examined documents and information stemming from associations of subsectors of the EII, such as the European Chemical Industry Council (CEFIC).

A key input to the report has also been a stakeholder workshop held on 13 September 2024, as well as a follow-up exchanges with stakeholders with relevant insights to be reflected on in the report. Insights from the workshop were used to refine especially the technology lists related to both the green and digital transition as well as the interpretation of results.

As outlined in Section 1.2, the **EII industrial ecosystem** comprises a whole range of different industries. Therefore, this report will focus on providing insights for the industrial ecosystem as a whole where possible, and will, where relevant, zoom in into one of the largest subsectors of the industrial ecosystem, namely the **chemical subindustry**. This approach is taken because the industrial ecosystem is highly scattered, and a focus will enable providing a clearer picture of the trends and progress in this important subsector.

1.2. Scoping the EII industrial ecosystem

The **Energy Intensive Industries (EII) industrial ecosystem** covers the chemicals, steel, pulp and paper, plastics, mining, extraction and quarrying, refineries, cement, wood, rubber, nonferrous metals, ferro-alloys, industrial gases, glass and ceramics industries[13]. In terms of the statistical classification of economic activities in the European Community (NACE), the industrial ecosystem definition includes:

- C16 Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
- C17 Manufacture of paper and paper products
- C19 Manufacture of coke and refined petroleum products
- C20 Manufacture of chemicals and chemical products
- C22 Manufacture of rubber and plastic products
- C23 Manufacture of other non-metallic mineral products
- C24 Manufacture of basic metals

The sectors included in the industrial ecosystem are characterised by a high energy and carbon intensity and by being at the starting point of many value chains, providing raw, processed and intermediate materials rather than finished goods. The EII industrial ecosystem is also very closely interlinked with several downstream sectors as well as energy providers and waste and recycling industries.

This industrial ecosystem is hence critically important to the whole economy. In addition, the EII industrial ecosystem employs about 7.8 million people in Europe and provides a value added of EUR 549 bn, representing 4.55% of the EU total. In total, there were almost

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[10] European Commission (2023) Transition pathway for the chemical industry. Retrieved from: https://data.europa.eu/doi/10.2873/873037

[11] EUROFER (2023) The European metals sector embarks on Transition Pathway to enable the EU Green Deal and Digital Agenda. Retrieved from: https://www.eurofer.eu/press-releases/the-european-metals-sector-embarks-on-transition-pathway-to-enable-the-eu-green-deal-and-digital-agenda

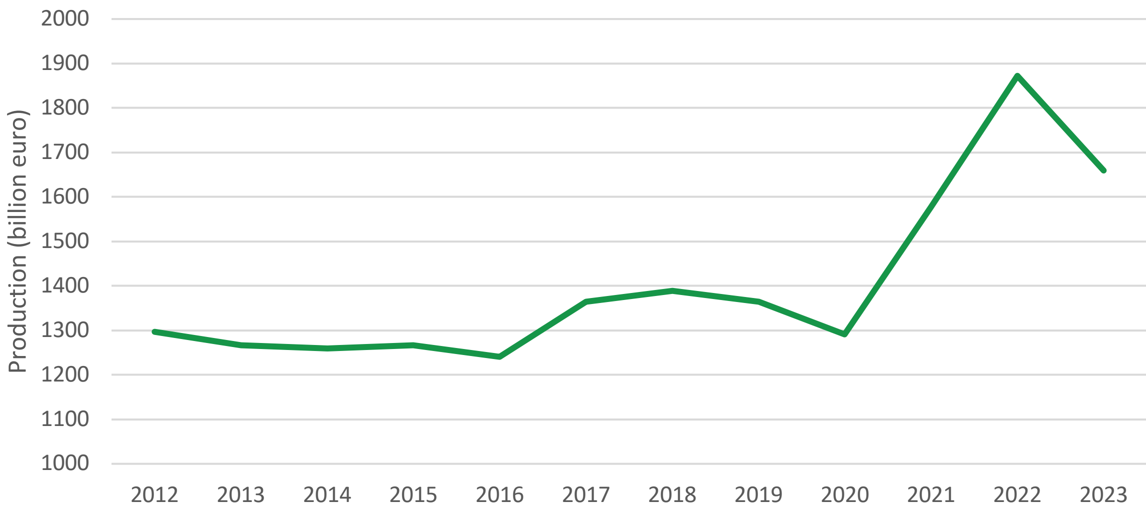
[12] European Commission (2023) Transition pathway for the chemical industry. Retrieved from: https://ec.europa.eu/docsroom/documents/54595

[13] European Commission (2021) Commission Staff Working Document. For a resilient, innovative, sustainable and digital energy-intensive industries ecosystem: Scenarios for a transition pathway. Retrieved from: https://ec.europa.eu/docsroom/documents/47059

550 000 firms in the industrial ecosystem in 2018[14], of which about 99% are SMEs[15]. About 51% of the employees in the industrial ecosystem are employed in SMEs, and SMEs represent 31% of the industrial ecosystem turnover and 37% of the value added[16]. In terms of added value, the sector 'chemicals and chemical products' had the highest gross value added in the industrial ecosystem in 2018. The sector 'rubber & plastic products' had the largest employment[17].

The total production value for the EII industrial ecosystem gives insight into the production performance of the overall industrial ecosystem. Data on production were extracted from the PRODCOM dataset of Eurostat[18]. PRODCOM statistics reveal the total values of production of manufactured goods conducted by enterprises located in the EU27. The EII industrial ecosystem is delineated by the NACE 2 classification based on weights identified in the Annual Single Market Report[19]. Figure 2 presents the weighted sum of production of manufactured goods aggregated at NACE 2-digit level for the EII industrial ecosystem (in billion EUR).

Figure 2: Evolution of the production value in the EII industrial ecosystem



Source: IDEA Consult based on Eurostat (prom)

Figure 2 shows that from 2012 to 2018, the production value increased slightly. In 2020, a drop in production value is noticeable, which can be attributed to the COVID-19 crisis. The Annual Single Market Report (2021) corroborates that the annual production in EII decreased significantly in 2020, with drops ranging from around 22% in the steel sector, 10 to 16% in cement, and 1 to 11% in non-ferrous metals. These drops are largely driven by declines in demand in downstream industries, such as the automotive industry. In 2021 and 2022, a general strong recovery was achieved, with economic conditions easing, consumer spending increasing, and governments rolling out recovery packages. Nevertheless, there was a distinction in recovery, with some EII products such as metals and minerals experiencing increased demand, and others experiencing difficulties in securing energy supplies or suffering from shortages of other products (e.g., microchips,

[14] European Commission (2022) Annual Single Market Report 2022. Retrieved from: https://ec.europa.eu/docsroom/documents/48877

[15] European Commission (2021) Commission Staff Working Document. For a resilient, innovative, sustainable and digital energy-intensive industries ecosystem: Scenarios for a transition pathway.

[16] Idem

[17] European Commission (2021) Annual Single Market Report 2021. Retrieved from: https://commission.europa.eu/system/files/2021-05/swd-annual-single-market-report-2021_en.pdf

[18] Eurostat (n.d.) Industrial production statistics introduced – PRODCOM. Retrieved from: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Industrial_production_statistics_introduced_-_PRODCOM

[19] European Commission (2021) Annual Single Market Report 2021.

leading to decreased production in downstream sectors, such as automotive, and hence in demand for several EII products)[20]. Energy prices continue to play an important role in the competitiveness of the chemical subindustry. While the war in Ukraine also had an impact on the prices of the manufactured and sold goods in the industrial ecosystem in 2022, energy prices remain higher than pre-war levels compared to other competing regions. More globally, these prices impact the chemical subindustry as they are not only used for the purpose of energy but also as a feedstock thus further impacting the subindustry when prices are high[21]. Subsequently, the situation on the energy market and the energy shock explains the drop in production value in 2023. Indeed, the production of basic metals, chemicals, non-metallic minerals and paper, for which energy costs represent a much bigger share of production costs, declined[22].

Given the wide range of sectors encompassed by the industrial ecosystem, this report will -where relevant- focus on **the chemical subindustry**. The chemical subindustry plays a crucial role in the European economy, as most goods manufactured in Europe depend on chemicals for various functions. For example, chemicals are essential in the production of pharmaceuticals, electronics, batteries for electric vehicles, and construction materials[23]. The European Chemical Industry Council (CEFIC) indicates that in 2021, the sector provides about 1.2 million direct highly skilled jobs and creates an estimated 3.6 million indirect jobs and supports around 19 million jobs across all value supply chains[24].

With EUR 760 bn in sales, the EU27 remained the second-largest chemical producer worldwide in 2022, after China having EUR 2 390 bn in sales[25]. In the EU27, 30% of the sales came from Germany, 18% from France, 11% from the Netherlands and 9% from Italy. In terms of types of chemicals, 27% of sales represented petrochemicals[26].

This was followed by decreased figures for the EU27 in 2023, with EUR 655 bn in sales, making 12.6% of global sales in percent[27]. Indeed, CEFIC reports that **2023 has been a turbulent year for the industry**, with the Russian war against Ukraine, weak demand, high energy costs, rising interest rates and inflation, leading to a 10.6% **decline in production** and 74.1% **decline in capacity utilisation** in the EU27[28].

Yet, in the Chemical Trends report (June 2024)[29], CEFIC indicates that the overall **chemicals business climate is now more stable,** the sector is over its ultimate low in terms of output and capacity utilisation and is showing a positive trend. Nevertheless, production is still significantly lower than in the pre-COVID period, and many chemical subindustry downstream users (such as rubber, plastics, textiles, computer production) are still showing downwards trends.

In general, the EU chemical subindustry is energy intensive and under severe competitive pressure. It faces challenges that include increased international competition, rising energy and feedstock prices, pressure to increase resource efficiency, new regulations, and the need for innovation.

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[20] European Commission (2024) Monitoring the twin transition of industrial ecosystems – Energy intensive industries. Retrieved from: https://data.europa.eu/doi/10.2826/65518

[21] CEFIC (2024) Chemical Monthly Report (CMR): Ongoing weak demand, export improvement, but low chemical business confidence.

[22] Bruegel (2023) Policy Brief. Adjusting to the energy shock: the right policies for European industry. Retrieved from: https://www.bruegel.org/policy-brief/adjusting-energy-shock-right-policies-european-industry

[23] European Commission (2021) Commission Staff Working Document. For a resilient, innovative, sustainable and digital energy-intensive industries ecosystem: Scenarios for a transition pathway.

[24] CEFIC (2023) Cefic Views on the EU's Free Trade Agenda. Retrieved from: https://cefic.org/app/uploads/2023/10/Cefic-views-on-the-EU-Free-Trade-Agenda.pdf

[25] As a comparison, in 2002, Europe was the largest chemical producer and the EU27 share of global chemical market dropped sharply from 27% in 2002 to 14% in 2022.

[26] CEFIC (2023) 2023 Facts and Figures Of The European Chemical Industry. Retrieved from: https://cefic.org/a-pillar-of-the-european-economy/facts-and-figures-of-the-european-chemical-industry/

[27] VCI (2024) Chemiewirtschaft in Zahlen. Retrieved from: https://www.vci.de/vci/downloads-vci/publikation/chiz-historisch/chemiewirtschaft-in-zahlen-2024.pdf

[28] CEFIC (2023) 2023 Facts and Figures Of The European Chemical Industry. Retrieved from: https://cefic.org/a-pillar-of-the-european-economy/facts-and-figures-of-the-european-chemical-industry/

[29] CEFIC (2024) Chemical Monthly Report – June 2024. Retrieved from: https://cefic.org/cefic-chemicals-trends-report/

2. Green transition

2.1. Industry efforts to green the industrial value chain

What progress has the industry made in taking action for the environment?

- The fact that **green transition-related patents account for 20% to 24% of all patents filed within the EII industrial ecosystem** highlights the importance of technology development in driving the green transition and underscores the challenges of reducing emissions in Energy Intensive Industries. A markable increase in the year of the COVID-19 pandemic is evident, highlighting the importance of creating new innovations during the pandemic.

- In 2024, **17% of companies in the EII industrial ecosystem have adopted strategies to reduce their carbon footprint** and become climate neutral or negative, showing limited commitment.

- EII companies prioritised measures that focus on **minimising waste,** with an increase from 46% in 2021 to 69% in 2024. This was followed by **energy saving measures**, adopted by 57% of companies, and materials saving efforts, which were prioritised by 55% of companies. A global increase in the adoption of environmental measures from 2021 to 2024 underpins the overall prioritisation of minimising waste and enhancing resource efficiency in support of overall green transition efforts.

- **Environmental startups in the chemical subindustry predominantly lie in the area of advanced manufacturing technologies** with a total of 72 startups created between 2015 and 2023. In addition, startups also focus on **recycling technologies**, and to a less extent, clean production technologies, renewable energy and energy saving technologies.

- The majority of EII companies **invest less than 5% of annual turnover in environmental technologies and measures.** A third of all companies and over 50% of high-emitting businesses reported access to capital as a major obstacle. Following the results from the Eurobarometer, 68% of EII companies received private funding from a bank, investment company or venture capitalist to produce green products or services, compared to 42% that received funding for enhancing resource efficiency.

- **Venture capital investments** for the chemical subindustry lie predominantly in the area of **recycling technologies** over the period 2015-2024, highlighting the relative importance of recycling technologies as a topic for young companies.

2.1.1. Technology generation

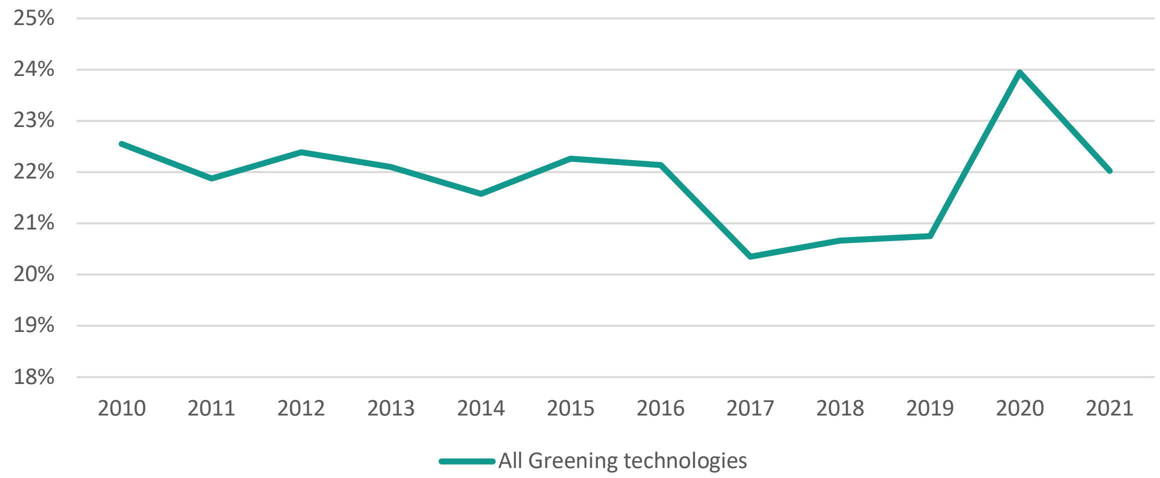
Technology development in EII has been captured based on the patenting activities related to specific sectoral activities[30].

Looking at the technologies related to the green transition, the Figure below presents the share of all greening patents in all patents filed for the EII industrial ecosystem among the EU27 industrial ecosystems. Figures of between roughly 20% and 24% showcase the relative importance of green transition patenting for the EII and the challenges associated

[30] The analysis is based on 'transnational patents' (Frietsch/Schmoch, 2010) (i.e. PCT/WIPO filings or direct applications at the EPO, excluding double counts) and was conducted on an extended version of the EPO's Worldwide Patent Statistical Database that Fraunhofer ISI implemented locally. Technologies-relevant-to-ecosystems, in this case the EII industrial ecosystem, are defined based on a search that refers to patent classifications (IPC) and/or use keywords to identify relevant applications across classes.

with tackling the abatement of EII emissions[31]. A markable increase in the year of the COVID-19 pandemic is evident, highlighting the relative importance of creating new innovations during the pandemic.

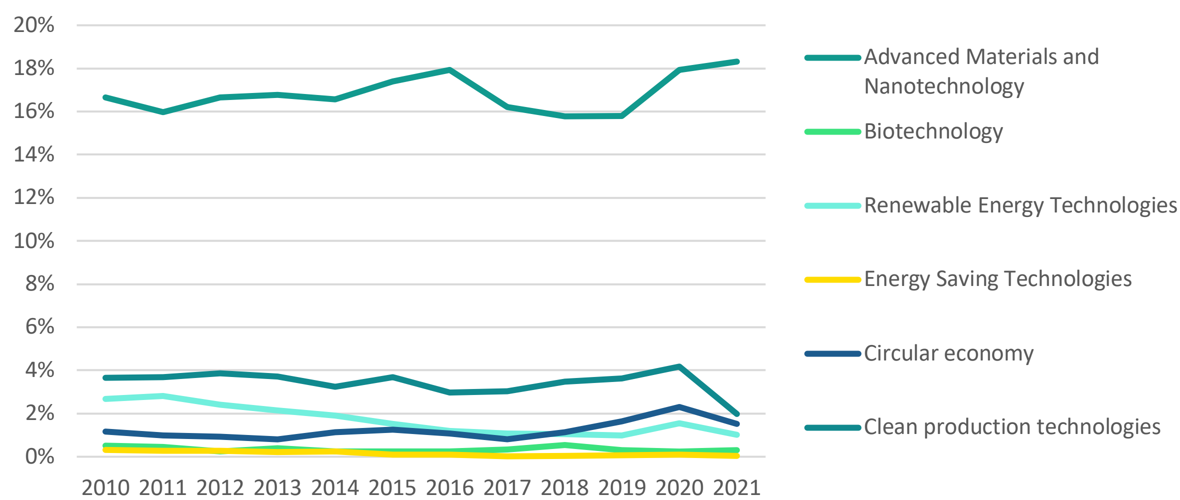
Figure 3: Share of green transition related patents in all patents filed for the EII industrial ecosystem among the EU27 industrial ecosystems



Source: Fraunhofer based on PATSTAT

At the level of green transition technologies, advanced materials clearly lead the patenting activities related to the EII industries (see Figure 4). Other technologies show lower levels of patenting activity related to this industrial ecosystem, with clean production technologies being the second most important and showcasing an increasing trend in recent years. Also patenting activities related to the circular economy have been increasing in importance since 2017, being the third most important area of patenting in 2020, followed by renewable energy technologies, showing an increasing trend since 2019 after experiencing a high 2011 followed by a subsequent decline.

Figure 4: Share of respective green transition technologies in overall patents filed in EII industrial ecosystem



Source: Fraunhofer ISI based on PATSTAT

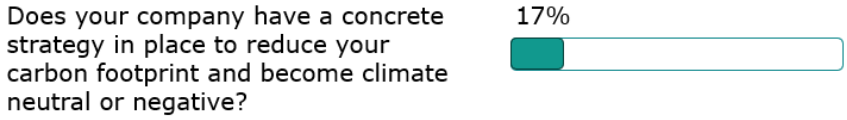
[31] EPO (n.d.) Solutions for carbon-intensive industries. Retrieved from: https://www.epo.org/en/searching-for-patents/technology-platforms/clean-energy/carbon-intensive-industries

2.1.2. Uptake of green technologies

The adoption of technologies in the EII industrial ecosystem has been investigated in detail by the Eurobarometer 2024 and has been complemented by a large-scale CATI survey conducted as part of the EMI project over the period from July-September 2024 with a sample of 672 companies across the EII subindustries.

According to the Eurobarometer 2024 survey results, 17% of companies have a concrete strategy to reduce carbon footprint or become climate neutral or negative.

Figure 5: Share of companies in EII industrial ecosystem that has adopted a strategy to reduce carbon footprint.



Source: Eurobarometer survey 2024

As shown in Figure 6, in 2024, **the most widely adopted environmental measure among EII companies was minimising waste** as indicated by 69% of respondents. This was followed by energy saving measures, adopted by 57% of companies, and materials saving efforts, which were prioritised by 55%. By comparison, in 2021, companies' main priority was recycling (48%), followed by minimising waste (46%) and energy saving (44%) and saving materials (43%). A global increase in the adoption of environmental measures from 2021 to 2024 underpins the overall prioritisation of minimising waste and enhancing resource efficiency in support of overall green transition efforts. Minimising waste has seen the highest increase in share (+23%), followed by saving energy (+13%) and saving materials (+13%), whereas recycling has not witnessed the same increase (+2%).

Figure 6: Share of firms indicating the adoption of environmental measures

Environmental measures	***Share of adoption (2021)***	***Share of adoption (2024)***
Minimising waste	46%	69%
Saving energy	44%	57%
Saving materials	43%	55%
Recycling, by reusing material or waste within the company	48%	50%
Saving water	33%	44%
Designing products that are easier to maintain, repair or reuse	26%	37%
Using predominantly renewable energy	9%	29%
Selling your residues and waste to another company	19%	24%
Switching to greener suppliers of materials	19%	21%

Source: Eurobarometer survey 2024.

The efforts of companies within the EII industrial ecosystem to advance the green transition are concentrated on several key technological areas. These technological areas aim to drive sustainability, reduce environmental impact, and enhance the overall efficiency of the industrial ecosystem. They include:

- energy saving technologies

- recycling technologies
- renewable energy
- clean production technologies
- advanced materials

Although the green and digital transition of the EII industrial ecosystem are intertwined, this report sets out to explore the transition and technological developments thereunder independently. Given the diverse nature of the EII industrial ecosystem, the report zooms in on the chemical subindustry as a focal point for select aspects of the analysis, highlighting the relevance of certain technologies for this industry. Where this is the case, it is clearly indicated.

According to the EMI survey, 55% of EII companies have invested in energy saving technologies in 2024, followed by 40% of companies investing in waste management technologies, 38% in clean production technologies and 33% in advanced materials.

Figure 7: Adoption of green technologies by EII companies

Green technologies	***Share of adoption***
Energy-saving technologies	55.24%
Waste management technologies	40.00%
Clean production technologies	38.10%
Advanced materials	32.86%
Biotechnology	7.14%
Carbon capture technologies	7.14%

Source: EMI Enterprise Survey 2024

Energy saving technologies

Given the energy intensive nature of the **EII industrial ecosystem**, the implementation of energy saving and efficiency technologies is of high importance. Energy efficiency, in this context, refers to the ability to produce the same products but consuming less energy[32]. This approach not only reduces energy costs but also minimizes environmental impact, which contributes to the sustainability goals of the respective industries.

Technologies to increase energy efficiency include process improvement (controlling and optimising energy consumption), implementation of heat upgrade technologies throughout production processes, recovery of waste heat energy, conversion of waste heat to power, optimising cooling, and electrification, among others[33]. Electrification represents the transformation of energy sources to the use of electricity to power industrial activities in EII and paves the way for the uptake of further renewable energies, leading to energy saving potential[34]. There are a particularly high number of energy efficiency demonstration projects in the steel, non-ferrous metals and cement industries, though energy efficiency

[32] European Parliament (2020) Energy-intensive industries. Challenges and opportunities in energy transition. Retrieved from: https://www.europarl.europa.eu/RegData/etudes/STUD/2020/652717/IPOL_STU(2020)652717_EN.pdf
[33] European Commission (2023) Scaling up innovative technologies for climate neutrality – Mapping of EU demonstration projects in energy-intensive industries. Retrieved from: https://data.europa.eu/doi/10.2777/926968
[34] IEA (n.d.) Electrification. Retrieved from: https://www.iea.org/energy-system/electricity/electrification

technologies are represented across all EII[35]. The main barrier for energy saving technologies and their uptake is related to their capital-intensive nature, which competes with other investments such as in new production capacity[36].

In the **chemical subindustry**, energy saving efforts focus on improving process optimisation in terms of energy consumption, including also the construction of new and more energy efficient facilities[37]. Selected technologies that can support in improving energy efficiency include upgrading motors, drives, and control valves used in pumping systems moving fluids, including the application of digital technologies in connection with these[38].

Recycling technologies

Across the **EII industrial ecosystem,** recycling technologies remain important, ranging from technologies related to the sourcing of materials, ensuring recycling is inherently possible, to valorisation of the related technologies, to end of life technologies that focus on separation and recycling based on specific underlying processes depending on the respective EII[39].

There are two main types of recycling technologies identified in the **chemical subindustry**. While **mechanical recycling** involves processing plastic waste into secondary raw materials or products without significantly altering the material's chemical structure, **chemical recycling** converts polymeric waste back into secondary raw materials or recycled feedstocks, reducing the need for virgin fossil resources. This process transforms the chemical structure of waste materials into the underlying building blocks, which are reused as secondary raw materials. These processes, including depolymerisation, pyrolysis, gasification, and solvolysis, address the deteriorating quality of polymers after mechanical recycling cycles[40]. Chemical recycling has as benefits that it gives value to otherwise unused plastic waste, it produces plastics of similar quality to virgin feedstock, it reduces the use of fossil resources, and it reduces CO_2 emissions otherwise associated with incineration and conventional production processes.

Certain breakthrough upcycling technologies are now commercially scalable[41]. These methods efficiently recycle various plastic wastes, including hard-to-recycle types, into high-purity products like waxes, oils, and solvents for different industries. By using plastic waste as feedstock, they enable the circular production of fossil-free chemicals[42].

Renewable energy technologies

The **EII** as major energy consumers can play an important role in integrating renewable energy sources into the economy. Depending on the industry, there are different mature technical options, such as the direct use of renewable resources, electrification, and the

[35] European Commission (2023) Scaling up innovative technologies for climate neutrality – Mapping of EU demonstration projects in energy-intensive industries. Retrieved from: https://data.europa.eu/doi/10.2777/926968
[36] European Parliament (2020) Energy-intensive industries. Challenges and opportunities in energy transition. Retrieved from: https://www.europarl.europa.eu/RegData/etudes/STUD/2020/652717/IPOL_STU(2020)652717_EN.pdf
[37] CEFIC (2023) Energy Consumption. Retrieved from: https://cefic.org/a-pillar-of-the-european-economy/facts-and-figures-of-the-european-chemical-industry/energy-consumption/
[38] ABB (2023). Energy efficiency opportunities in chemical manufacturing. Retrieved from: https://library.e.abb.com/public/27d8a198b3154b2abe366a14ad1f5009/ABB_WhitePaper_Chemical%20manufacturing_20230911.pdf
[39] European Commission (2023) ERA industrial technology roadmap for circular technologies and business models in the textile, construction and energy-intensive industries. Retrieved from: https://op.europa.eu/en/publication-detail/-/publication/32f12c4b-9d89-11ed-b508-01aa75ed71a1/language-en
[40] CEFIC (n.d.) Top Questions About Chemical Recycling. Retrieved from: Retrieved from: https://cefic.org/a-solution-provider-for-sustainability/chemical-recycling-making-plastics-circular/top-questions-about-chemical-recycling/
[41] European Commission (2023) Transition pathway for the chemical industry. Retrieved from: https://data.europa.eu/doi/10.2873/873037
[42] CEFIC (n.d.) Top Questions about Chemical Recycling.

use of renewable hydrogen, sustainable biomass and bioenergy as a renewable feedstock or energy source to replace fossil fuels[43]. Indications related to the these include:

- **Green Hydrogen**: Fostering the creation and use of green hydrogen is a key EU priority as set out in the REPowerEU strategy of 2022[44], which is highly supported by the Commission. Importantly, the availability of decarbonised electricity at affordable prices is a major determinant of the speed and scale of green hydrogen adoption[45]. The **chemical subindustry** is a significant consumer and producer of hydrogen, including green hydrogen but also grey hydrogen, which can be used in chemical processes both as a feedstock and an energy carrier[46]. The 2023 annual progress report of the chemical transition pathway[47], which is a policy report based on stakeholder consultation, refers to the list of Important Projects of Common European Interest (IPCEI) which includes hydrogen related projects that focus on addressing hydrogen infrastructure needs [48].
- **Alternative fuels**: In the EII industrial ecosystem, biomass to energy refers to biomass used in the production of energy (bioenergy). This category covers also the use of waste and biomass to produce biofuels as a form of waste valorisation. In 2021, 59% of renewable energy consumption was based on biomass in the EU[49]. As the EII are a considerable energy consumer, relying on biomass to produce energy remains an important consideration in the uptake of renewable energy technologies across the industrial ecosystem.
- **Other technologies**: Other renewable energy technologies that are of relevance to the EII include energy storage technologies as well as heat pumps.

Clean production technologies

Clean production technologies allow to reduce the overall environmental impact of the EII industrial ecosystem. Examples of technologies include those that reduce the use of natural resources, limit production of waste and limit water or other resource consumption. With the relevant technologies in place for the EII, low carbon technologies have the potential to prevent up to nearly 60 Gt of CO_2 emissions if implemented in time for the next retrofitting cycle starting by 2030[50].

Clean production technologies for EII include technologies focussed on retrofitting as well as Carbon Capture Utilisation and Storage technologies and alternative feedstocks. Carbon Capture, Utilisation and storage (CCUS) involves capturing CO_2 from major sources like power generation or industrial facilities that use fossil fuels or biomass[51]. The International Energy Agency (IEA)[52] reports on approximately 45 commercial facilities that currently use CCUS for industrial processes, fuel transformation, and power generation. As for alternative feedstocks, this includes the identification of source materials feeding into the EII themselves.

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[43] European Commission (2021) Commission Staff Working Document. For a resilient, innovative, sustainable and digital energy-intensive industries ecosystem: Scenarios for a transition pathway. Retrieved from: https://ec.europa.eu/docsroom/documents/47059

[44] European Commission (n.d.) Hydrogen. Retrieved from: https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen_en

[45] European Commission (2021) Commission Staff Working Document. For a resilient, innovative, sustainable and digital energy-intensive industries ecosystem: Scenarios for a transition pathway.

[46] CEFIC (n.d.) Low-Carbon Technologies Projects: Mapping Investments And Projects Of The European Chemical Industry. Retrieved from: https://cefic.org/a-pillar-of-the-european-economy/low-carbon-technologies-projects/

[47] European Commission (2024) 2023 annual progress report – Transition pathway for the chemical industry. Retrieved from: https://data.europa.eu/doi/10.2873/78547

[48] European Commission (2024). 166 key cross-border energy projects published. Retrieved from: https://energy.ec.europa.eu/news/166-key-cross-border-energy-projects-published-2024-04-08_en

[49] European Commission (n.d.) Biomass. Retrieved from: https://energy.ec.europa.eu/topics/renewable-energy/bioenergy/biomass_en

[50] IEA (2021). Net Zero by 2050. A Roadmap for the Global Energy Sector. Retrieved from: https://www.iea.org/events/net-zero-by-2050-a-roadmap-for-the-global-energy-system

[51] IEA (n.d.) Carbon Capture, Utilisation and storage. Retrieved from: https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage

[52] IEA (n.d.) Carbon Capture, Utilisation and Storage. Retrieved from: https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage

In addition, **chemical companies** have started investing in the development of technologies enabling the utilisation of CO_2 (and CO) as alternative carbon feedstock[53], which presents a significant opportunity for the chemical subindustry in terms of reducing the environmental footprint. Feedstock based on biomass result in biomass-derived chemicals which are defined as chemical products that are wholly or partly derived from materials of biological origin (e.g. plants, algae, crops, trees, marine organisms and biological waste).

Advanced materials

Advanced materials include materials that facilitate recycling, support in reducing raw materials demand, and act in support of the end products that the industry is aiming to produce, enabling a higher added value. This includes the application of nanofibers, coatings, dyes, etc. with the aim of supporting special functions and superior performance compared to traditional materials. High performance coatings and surface treatments to enhance anticorrosion protection for example, can contribute to a better performance.

Advanced materials also act as enabler to the integration of renewables and batteries as well as circularity and recyclability in EII[54]. Advanced materials for a sustainable transformation of energy intensive industrial processes include a) porous materials for carbon dioxide capture and conversion into added value chemicals; b) electrocatalytic and catalyst materials free of critical raw materials; c) clean synthesis routes of porous materials (e.g. metallic foams) based on green chemicals; d) thermo-electric elements and materials for heat transfer for the conversion of (lost) heat energy to electricity, e) green steel, ceramics, aluminium and sintered products using cost efficient renewable power, f) electrochemical production ammonia as alternative to the energy intensive Haber-Bosch process[55].

2.1.3. Environmental startups in EII

Startups

Capturing information on startup creation allows to give insight into the novel technologies being generated related to a specific industry. Zooming in on the **chemical subindustry**, the analysis of startup generation has been compiled through a database encompassing Crunchbase and Net Zero Insights[56] data.

A total of **419 startups were created in relation to the chemical subindustry from 2015 to 2023, of which 133 were in support of the green transition**.

A look at the level of the **green transition related technologies** as presented in Figure 11 reveals which technologies are leading in startup creation. Companies in **advanced materials** stand out with a total of 72 startups created between 2015 and 2023. Recycling technologies are the second most important green transition technology in this regard, with 25 startups created during the same time period. Clean production technologies are the third most important technology with a total of 12 startups created over the indicated period. Renewable energy and energy saving technologies make up the least important technologies in terms of startup creation, which can be attributed to startups of this nature being generally associated with other industrial ecosystems such as renewable energy. A general data lag is present in the underlying data set, which shows global decline in startups captured from 2020.

To further illustrate the specific technologies, examples of startups related to the underlying technology are listed below:

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[53] CEFIC (n.d.) CO_2 Valorisation. Retrieved from: https://cefic.org/policy-matters/innovation/co2-valorisation/

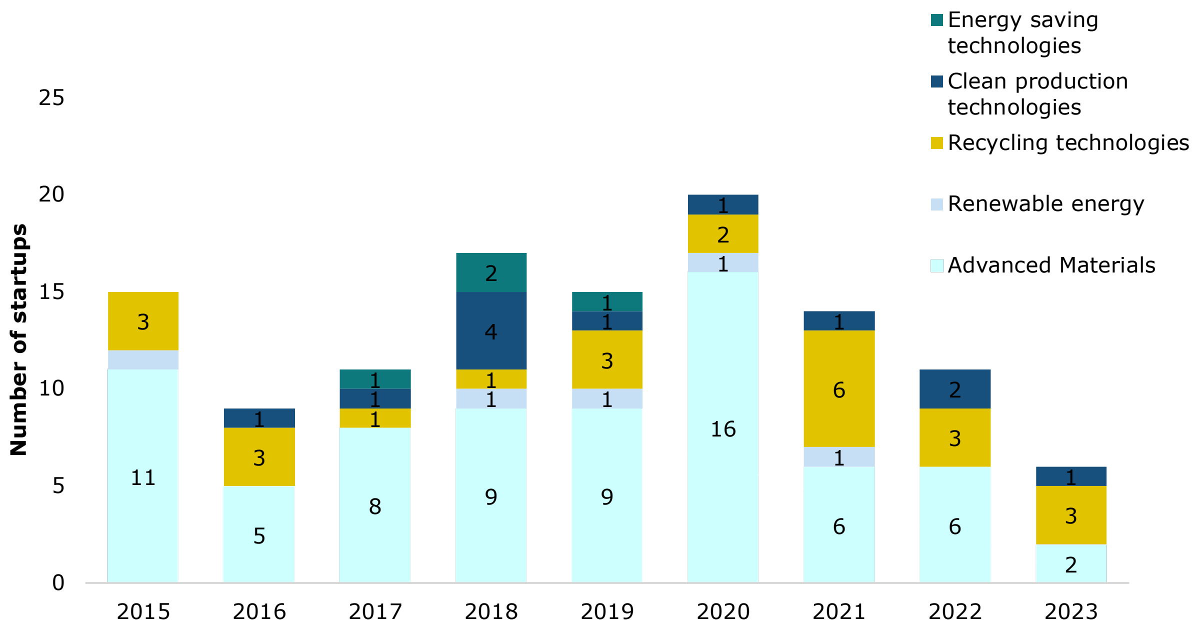
[54] European Commission (n.d.) Advanced Materials. Retrieved from: https://single-market-economy.ec.europa.eu/industry/advanced-manufacturing/advanced-materials_en

[55] Materials 2030 Roadmap (December 2022)

[56] www.crunchbase.com and https://netzeroinsights.com/

- **Traceless materials**[57] (advanced materials) was founded in 2020 in Germany as a company focussing on the circular bioeconomy developing degradable plastic free materials based on valorisation of plants from the agricultural industry.
- **UP Catalyst**[58] (advanced materials, clean production technologies) is an Estonian company created in 2019 that uses CO_2 emissions as input to develop carbon nanomaterials and graphite for uses in batteries & supercapacitors, paints & coatings, concrete and other composites.
- **HT Materials Science**[59] (energy saving technologies) is an Irish company that was created in 2018, which develops a heat transfer fluid for commercial and industrial heating, ventilation and air conditioning markets.
- **C1 Green Chemicals** [60] **,** (clean production technologies) is a German startup established in 2022, that develops a green methanol solution targeting CO_2 emissions reductions specifically for shipping and chemical subindustry.

Figure 8: Breakdown by green technology in the chemical subindustry



Source: Technopolis Group based on Crunchbase and Net Zero Insights

2.1.4. Private investments

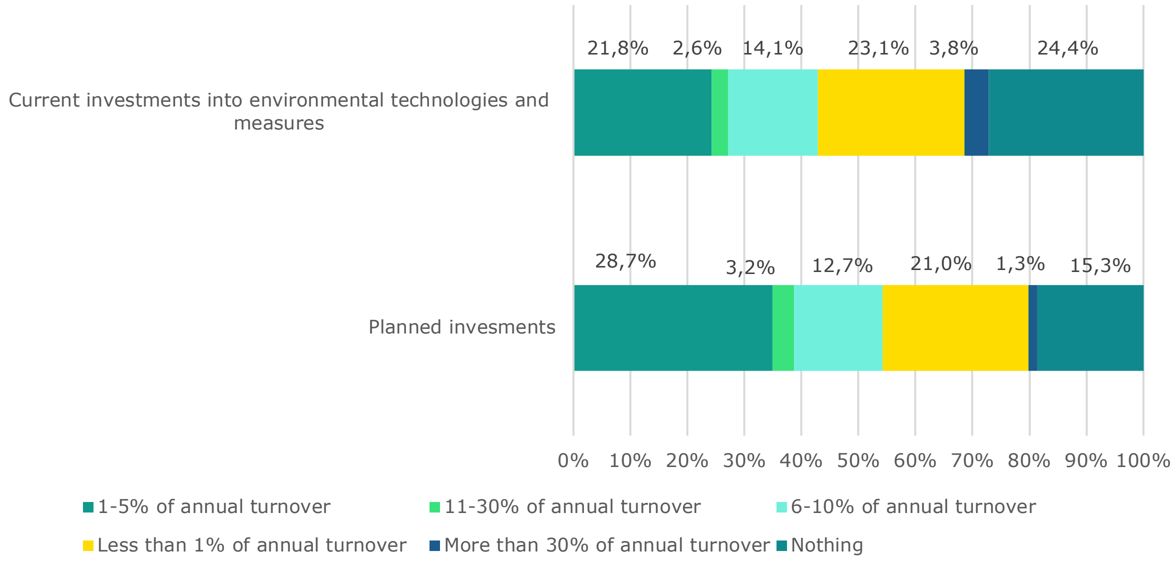
Private investments by companies in the EII industrial ecosystem are an important driver towards the green transition. However, according to the EIB 2023 Investment report, companies across the EII see the green transition rather as a risk than an opportunity. Companies were forced to take on emergency measures to cope with the impacts of the energy crisis in 2022, which were compounded by the Emissions Trading System. That being said, companies in the EII industrial ecosystem are more likely to change their

[57] https://www.traceless.eu/ and https://www.crunchbase.com/organization/traceless-materials
[58] https://upcatalyst.com/ and https://www.crunchbase.com/organization/up-catalyst
[59] https://htmaterialsscience.com/
[60] https://www.carbon.one/

business model to reduce pollution and environmental impact, with likewise higher incentives to explore investments in green products[61].

The EMI Enterprise Survey indicates that the **majority of EII companies invest less than 5% of annual turnover in environmental technologies and measures,** with 24% making no investments, 23% investing less than 1% of annual turnover, and 22% investing 1-5% of annual turnover at present. In terms of planned investments, only 15% will continue not to invest, while 29% plan to invest between 1 and 5% of their annual turnover, **representing a 7% increase.**

Figure 9: Level of investment of EII businesses into green technologies



Source: EMI Enterprise Survey 2024

One-third of companies overall and over 50% of high-emitting businesses reported access to capital as a major obstacle. Following the results from the Eurobarometer, 68% of EII companies received private funding from a bank, investment company or venture capitalist to produce green products or services, compared to 42% that received funding for enhancing resource efficiency.

Venture capital investments [62] **in the green transition for the chemical subindustry were not impacted by the global downturn in venture capital investments**, which saw a 38% decline as compared to 2022 (from EUR 427 bn[63] in 2022 to EUR 263 bn in 2023)[64]. The year 2023 saw a total of EUR 372 million in venture capital investments, up from EUR 203 million in 2022 (see Figure 12). The sharp incline in the recent years can be attributed to the increasing importance and emphasis placed on the chemical subindustry to reduce its overall environmental impact.

A total of **EUR 774 m in venture capital investments** has been attracted by chemicals young companies related to the green transition from 2015 to 2023, with a majority of

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[61] EIB (2024) Investment report 2023/2024: Transforming competitiveness. Retrieved from: https://www.eib.org/attachments/publications/20230323_investment_report_2023_chap5.pdf

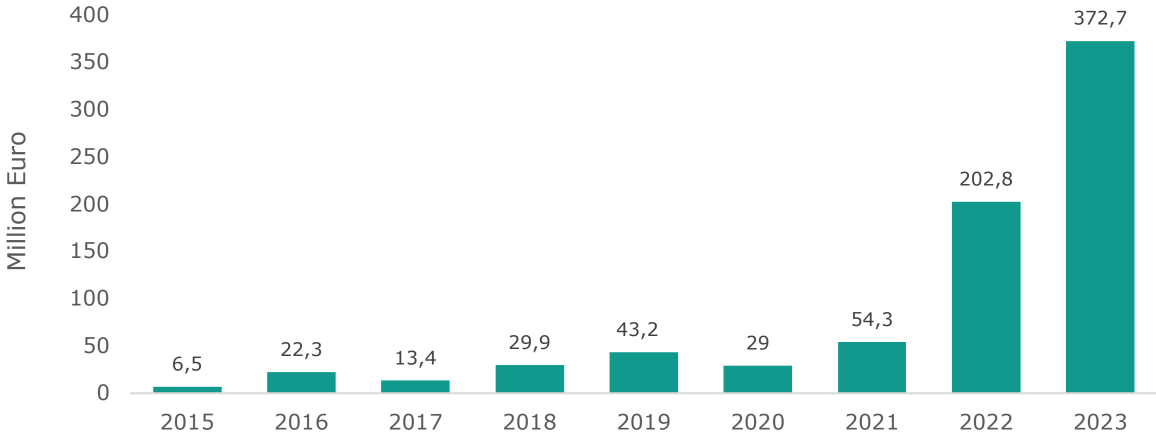
[62] Venture capital investments tracked in the Crunchbase and NetZero Insights data set. The data set looks at venture capital investments in young companies (age 10 years or less) and gives insights into the amount of investment related to the green transition, as well as investments related to technologies underpinning the transition, notably energy saving technologies, recycling technologies, renewable energy, clean production technologies and advanced materials in the chemical subindustry. Venture capital data remain sufficiently well reported that general trends can be observed however some data lags for the most recent year (2023) may be present.

[63] All currencies are based on current exchange rate of 1EUR = $US 1.0807, 29 October 2024

[64] Crunchbase (2024) Global Startup Funding In 2023 Clocks In At Lowest Level In 5 Years. Retrieved from: https://news.crunchbase.com/venture/global-funding-data-analysis-ai-eoy-2023/

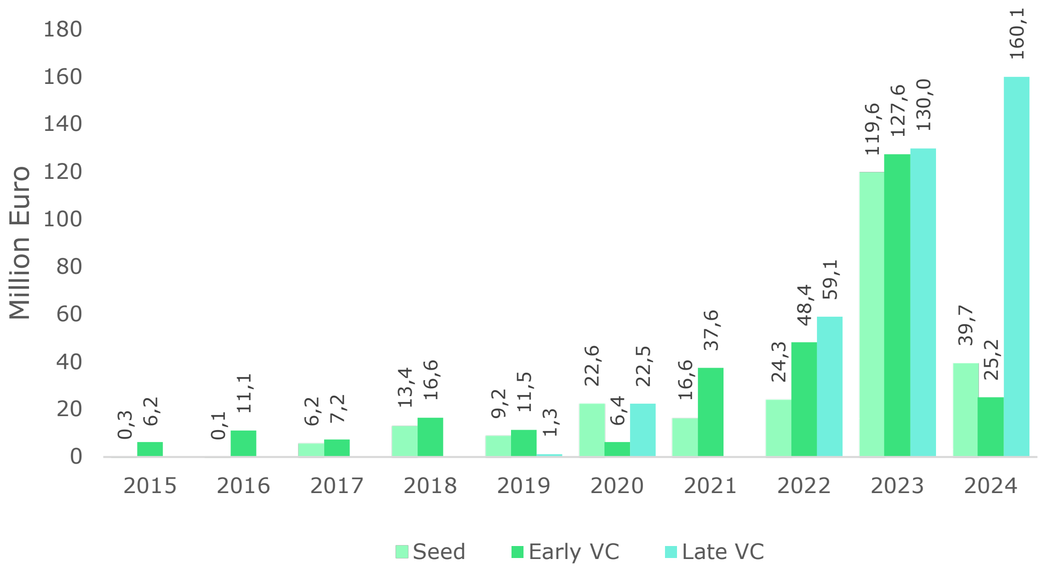
investments dedicated to the early VC phase (EUR 273 m), with late VC and seed funding on equal footing with EUR 213 m and EUR 212 m respectively from 2015 to 2023.

Figure 10: Venture capital investment into chemical young companies – green transition



Source: Technopolis Group based on Crunchbase and Net Zero Insights

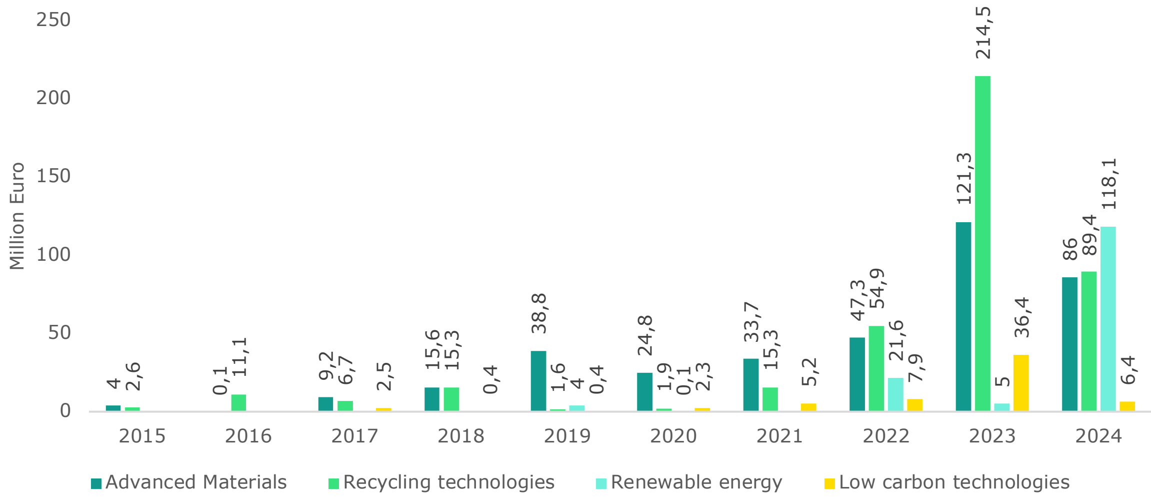
Figure 11: Venture capital investments stages into green transition of chemical young companies



Source: Technopolis Group based on Crunchbase and Net Zero Insights

Looking at the venture capital investments related to the underlying green technologies, recycling technologies leads with a total of EUR 413.2 m investments over the indicated period. This is followed by investments in renewable energy technologies (EUR 148.7 m) and investments related to advanced materials (EUR 380 m) over the indicated period.

Figure 12: Details on the VC investments per technology 2015-2024 – chemical young companies in the green transition



Source: Technopolis Group based on Crunchbase and Net Zero Insights

Details on the funding rounds of select young companies based on the Crunchbase and NetZero Insights dataset include:

- **APK**[65] (recycling technologies) is a German company founded in 2008 that develops solutions related to polymer recycling and has developed a dissolving process which allows for the separation of individual polymer types in mixed plastic waste, resulting in pure, clean plastic granulate with the character of a new product. It has raised a total of EUR 139 m in funding over six rounds.
- **C1 Green Chemicals**[66] (clean production technologies) is a German young company founded in 2022 that has raised a total of EUR 23.4 m in funding over six rounds. It focuses on green methanol production to decarbonise the shipping and chemical subindustry.

[65] https://www.crunchbase.com/organization/apk-aluminium-und-kunststoffe-ag
[66] Also known as Circular Carbon Chemistry https://www.carbon.one/ and https://www.crunchbase.com/organization/circular-carbon-chemistry

2.2. Framework conditions – assessment of the broader industrial ecosystem supporting the green transition

To what extent do framework conditions such as public financing and skills support the green transition?

- The EII industrial ecosystem received **EUR 10.5 bn in support from the European Regional Development Fund** for the period 2014-2020. Projects that addressed specifically the **green transition of EII accounted for EUR 2.88 bn.**

- 38**% of the identified EII ERDF projects contribute to the green transition, while 10% are active in advanced green technologies,** such as energy saving technologies, advanced materials and renewable energy technologies.

- While the **Horizon 2020 programme funded EUR 302.5 million** to projects classified under the EII industrial ecosystem, **Horizon Europe** has thus far provided **EUR 229.2 million** in funding.

- Under Horizon 2020**, 62.4% of the EC funding to EII projects contributed to the green transition**. For Horizon Europe, **71.9% of the EC funding** to EII projects contributes to the green transition.

- **The EII industrial ecosystem faces a mismatch and skills gap,** while having access to a qualified workforce throughout the regions and subindustries is a prerequisite for innovation. The **chemical subindustry** faces challenges related to up-skilling, re-skilling and sufficient supply of jobs at technical level to attract and keep talents**.** The share of professionals registered on LinkedIn and employed in the chemical subindustry with skills relevant to the green transition attained 17.88% in 2024, up from 6.14% in 2022.

2.2.1. Public investments supporting the green transition

In the context of this study, the **investments made in the green transition of the EII industrial ecosystem through public policy programmes** – i.e., the European Regional Development Funds, Cohesion funds, and the Framework Programmes – are examined through the combination of the databases Cohesion Open Data and Kohesio, as well as the database Community Research and Development Information Service (Cordis).

Cohesion policy

A key source of public funding that enables the green transition is the **EU's regional development funds**[67].

ERDF projects[68] that are related to the EII industrial ecosystem could be identified based on the codes of economic activity and additional keyword searches in the project descriptions. The total number of **ERDF projects in the EII industrial ecosystem** that could be identified in 2014-2020 was 8 873, representing a total funding of EUR 10.5 bn.

[67] For this analysis, two data sources have been used and merged, namely the Cohesion Open Data maintained by the European Commission and the Kohesio data. The latter contains more than 1.7 million projects and approximately 500 000 beneficiaries financed throughout the funding period 2014–2020 . For more information on the data sources and the approach, see the methodological report. See European Union (2022) Linking data: Kohesio platform. Retrieved from: https://data.europa.eu/en/publications/datastories/linking-data-kohesio-platform

[68] The European Regional Development Fund (ERDF) supports projects aimed to strengthen economic, social and territorial cohesion in the European Union. It aims to correct imbalances between regions enabling investments in a smarter, greener, more connected and more social Europe that is closer to its citizens. The ERDF finances programmes in shared responsibility between the European Commission and national and regional authorities in Member States.

The analysis shows that **about 27%** (or EUR 2.88 bn) **of the funding to EII ERDF projects supported the green transition**[69].

Some examples of EII projects supporting the green transition are described in Box 1.

Box 1. ERDF EII projects supporting the green transition

Projects focused on energy saving:

Chimcomplex S.A. Borzesti implemented the project 'High-Efficiency Cogeneration Plant with a capacity of up to 8 MWe at Chimcomplex S.A. Borzesti – Ramnicu ValceaBranch' in Romania.

Advanced materials

Connect Pyme 2016 — InnoBiorre — valorisation of agro-industrial waste to obtain high added value bioproducts, Spain Galicia

Preparation of nanomaterials biopolimericos using ionic liquids and supercritical CO_2 and their application in biomedicine and environment

Renewable energy projects

Progress in the development of pem electrolysers as a major component of the hydrogen-based renewable energy storage scheme, Germany

Production of biobutadieno from bioethanol

Recycling technologies

Development of biomorphic catalysts obtained from residual biomass for hydrogen production and bio-oil refining

Valorisation of natural resources as new materials: cataliticas and electrochemicals

Clean production technologies

New green chemistry: glycolate as a new biotechnological platform for the production of energy and industrial raw materials

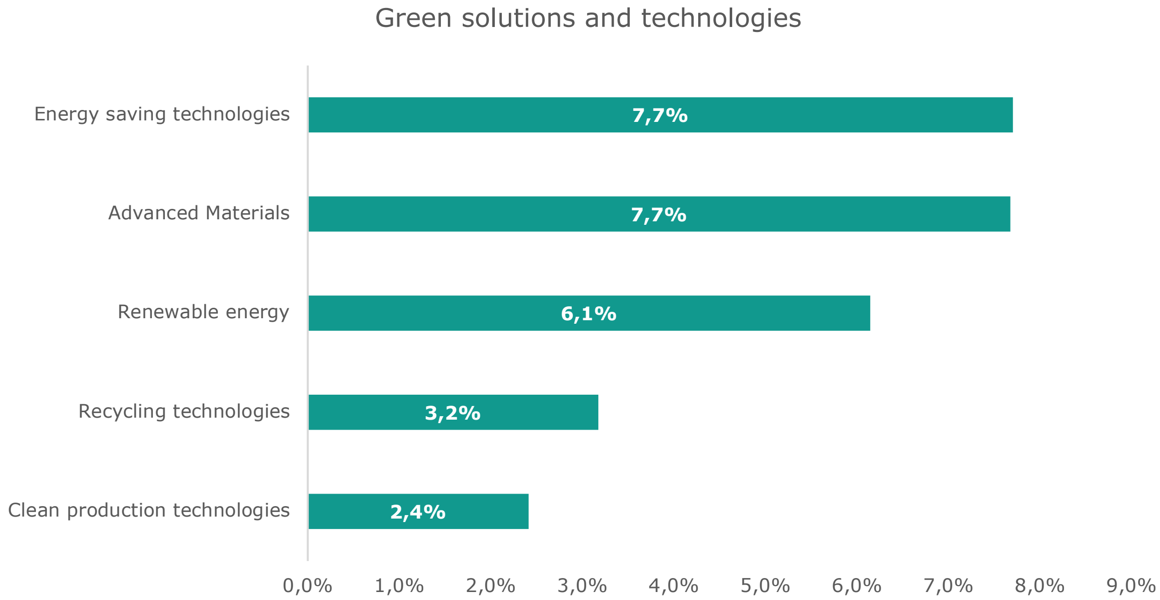
Optimisation of hydrothermal CO_2 reduction to develop an integrated CO_2 capture and utilisation process

Source: Technopolis Group based on Kohesio

In terms of number of projects, 38% of the identified EII projects contribute to the green transition (or 3 400 projects). Of this set of green projects, **10% are active in advanced green technologies**, such as energy savings and renewable energy technologies. In particular, Figure 15 shows that 8% of the EII projects contributing to the green transition focused on energy saving technologies and 8% on advanced materials.

[69] The projects related to the green transition were filtered in the same manner, using a selected list of green keywords that were also constructed for other parts of the data collection in this project.

Figure 13: Share of projects in 'advanced green technologies' in the total of ERDF EII projects that contribute to the green transition



Source: Technopolis Group based on Kohesio

Framework Programmes

EC Framework Programmes for Research and Innovation cover both Horizon 2020 (2014-2020) and Horizon Europe (2021-2027) in the analysis of the EII industrial ecosystem.

While the Horizon 2020 programme funded EUR 302.5 million to projects classified under the EII industrial ecosystem[70], Horizon Europe has thus far provided EUR 229.2 million in funding[71].

Under Horizon 2020**, 62.4% of the EC funding to EII projects contributed to the green transition**. For Horizon Europe, **71.9% of the EC funding** to EII projects contributes to the green transition. These shares point towards the high importance of the green transition, as supported by the Framework Programmes.

A high number of circularity-related projects are funded at EU level, that address the circularity of materials through recycling[72] e.g. the recycling of concrete.

Several calls in the Framework Programmes support EII projects contributing to the green transition. For instance, the Horizon Europe calls "Twin green and digital transition" and "a digitised, resource-efficient and resilient industry" under Cluster 4 "Digital, Industry and Space" are supporting several green EII projects. As illustration, one particular call "design and optimisation of energy flexible industrial processes" focuses on the twin green and digital transition providing a green productivity premium to discrete manufacturing, construction and EII, including process industries.

In addition, there are also some public-private partnerships like the Clean Steel Partnership (CSP) that aims to support the European steel sector to decarbonise and to transform into a vital, sustainable and circular industry[73]. The funding of the CSP comes from the Horizon

[70] The methodological report provides detailed insights into the methodology. In particular, the CORDIS data have been merged with the relevant EuroSciVoc data. EuroSciVoc connects projects to relevant scientific concepts, providing a deeper understanding of the research focus.
[71] Cut-off date: March 2024
[72] European Commission (2023), Scaling up innovative technologies for climate neutrality – Mapping of EU demonstration projects in energy-intensive industries. retrieved from: https://data.europa.eu/doi/10.2777/926968
[73] https://www.estep.eu/clean-steel-partnership

Europe programme and the Research Fund for Coal and Steel (EUR 700 million over the period 2021-2027), and the private steel sector (expected EUR 1 billion).

Examples of EII projects funded under Horizon 2020 and Horizon Europe supporting the green transition is described in Box 2.

Box 2. Horizon 2020 and Horizon Europe EII projects supporting the green transition

The Horizon 2020 project, **NEMO**[74] (Near-zero waste recycling of low-grade sulphidic mining waste for critical-metal, mineral and construction raw material production in a circular economy) ran between 2018-2022 and received a EU contribution of EUR 12.4 million.

Sulphidic mining waste from the production of Cu, Pb, Zn and Ni represents the largest volume of extractive waste in Europe, and when poorly handled it can lead to major environmental problems. Therefore, NEMO - through four pilots and two case studies in Finland and Ireland – developed, demonstrated and exploited new ways to valorise sulphidic mining waste. The pilots were located at key points in the near-zero waste flowsheet, including the recovery of valuable metals, the safe concentration of hazardous elements, the removal of sulphur as sulphate salts, and using the residual minerals in cement and construction products.

The **HyInHeat**[75] project brings together 30 partners from 12 different countries across Europe, and it received EUR 24 million in EU funding. The project started in 2023 and it will run until 2026.

HyInHeat's primary objective is to advance hydrogen as a fuel source for high temperature heating processes in EII. By enabling efficient hydrogen-based combustion systems, the project seeks to decarbonize the heating and melting processes throughout nearly the entire production chains of these sectors. In order to achieve this objective, various equipment and infrastructure components – including furnaces, burners, infrastructure, measurement and control technologies – are being redesigned, modified and implemented across 8 demonstration units located in technical and industrial sites.

The Horizon Europe **FLEXIndustries**[76] project (Digitally-enabled FLEXible Industries for reliable energy grids under high penetration of Variable Renewable Energy Sources (VRES)) started in 2022 and will end in 2026. It receives EU funding of EUR 12.4 million. The initiative comprises 16 large enterprises, 6 research institutes, 2 universities, 8 SMEs, and 8 NGOs. The project is characterised by its multi-disciplinarity and multi-scalability aimed at improving energy efficiency, achieve energy savings and reduce life cycle costs in the sectors of automotive, biofuels, polymers, steel, pulp and paper, pharmaceuticals and cement. FLEXIndustries develops a Dynamic Energy & Process Management Platform to analyse, monitor industrial energy intensive processes while managing a demand-response mechanism and providing grid services. The project also integrates innovative energy technologies such as battery energy storage systems and waste heat recovery, along with digital tools for operation and control.

Source: authors based on Cordis and project websites

[74] https://cordis.europa.eu/project/id/776846
[75] https://hyinheat.eu/
[76] https://cordis.europa.eu/project/id/101058453

2.2.2. Skills supply and demand underpinning the green transition

The EII transition pathway underlines that the **EII industrial ecosystem faces mismatches and gaps in skills**, while having access to a qualified workforce throughout the regions and sectors is a prerequisite for innovation. Moreover, the EII face a shift to new production processes with new skills required. As a result, some occupational groups will see their task profile changing and new occupations will emerge. These new occupations will mainly require medium and high skills, while low-skilled professionals might be more exposed to unemployment[77].

A study[78] in Flanders, Belgium, identified the most important skills needs for the EII. To encourage the green transition, it was indicated that technical knowledge and skills were needed in sustainable design, renewable energy, efficient and circular production and green business.

The **chemical subindustry** is also facing specific challenges related to skills. They are experiencing exponential change which affect the nature of the work and jobs, and R&D and specialised solutions are increasingly important to remain competitive. The transition pathway of the chemical subindustry underlines the following main focus areas[79]:

- Up-skilling and re-skilling of the workforce across all levels of seniority in the industry to meet the demands of both regulators and society for achieving a more sustainable chemical subindustry. Sectorial roadmaps for skills as well as education support would be needed to bridge the gap between the fast-changing new skills demands by the companies.
- Sufficient supply of jobs at technical level through corporate training, recruiting and retaining strategies to attract and keep talents in the chemical subindustry.

The 2023 progress report of the transition pathway indicates that more than 70% of actions in this regard have already been launched, and 11% are already finalised. A recent Erasmus+ project, "ChemSkills", is one of the initiatives aiming to facilitate the green and digital skills transformation of the chemical subindustry (see Box 3).

Box 3. The ChemSkills project

The ChemSkills[80] project, an Erasmus + Blueprint project, aims to gather skills intelligence, identify gaps between European chemical subindustry needs and education currently offered, develop a sector-specific skills strategy and design concrete education and training solutions for quick take-up at regional and local levels, and for new occupations. The project started in 2023, will run until 2027, and comprises 33 partners located in 13 countries. ChemSkills receives an overall contribution of EUR 3,985,100.

The project divides its activities into 5 different work packages and 5 sub-work packages that aim to address the sector's skills gaps. Each work package focuses on a specific area including activities and initiatives such as delivering trainings, helping with project management and coordination across the partners and communicating project results. Work Package 3 "Sectoral Skills Intelligence and Education Provision" plays a pivotal role as it will, amongst others, provide a roadmap based on the skills-agenda. The subsectors are divided into plastics, consumer chemicals, fertilisers, rubber, pharmaceuticals and petrochemicals.

Source: the authors based on web searches

[77] European Commission (2019) Masterplan for a competitive transformation of EU energy-intensive industries enabling a climate-neutral, circular economy by 2050. Retrieved from: https://data.europa.eu/doi/10.2873/854920
[78] Roland Berger (2021) A green Skills roadmap for the climate transition in the energy intensive industry. Retrieved from: https://klimaat.be/doc/just-transition-jobs-2023-flanders.pdf
[79] European Commission (2024) 2023 annual progress report – Transition pathway for the chemical industry. Retrieved from: https://data.europa.eu/doi/10.2873/78547
[80] https://www.chemskills.eu/

In order to provide insights into the **skills demand and skills supply in the EII industrial ecosystem**, this study draws upon two databases, namely the Cedefop database and LinkedIn[81].

Skills demand

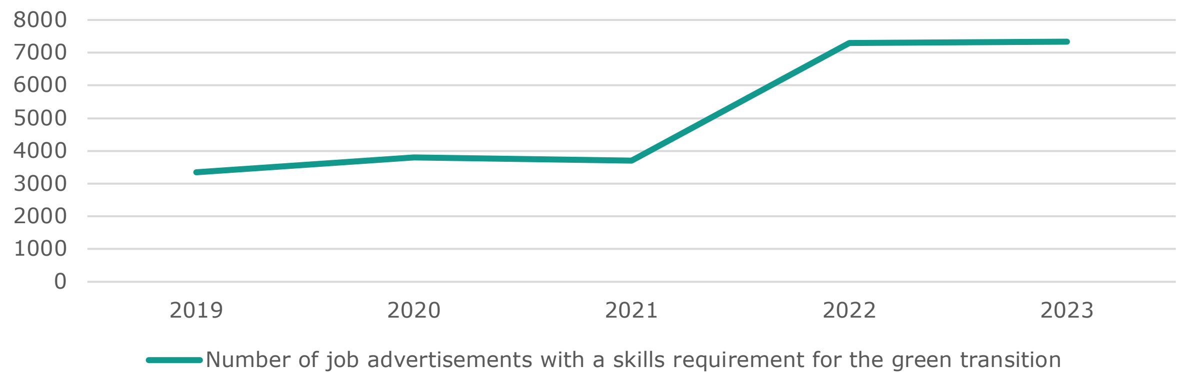
Skills demand in the EII industrial ecosystem has been analysed following the skills intelligence insights of Cedefop, the European Centre for the Development of Vocational Training[82]. The websites reflect the characteristics of the local labour markets in terms of geographical distribution, ranging from 50 sites in Belgium and the Netherlands, to three in Luxembourg. For each job advertisement, there is data on the characteristics of the job, the employer, and job requirements[83].

Green skills have been defined as skills related to environmental protection, environmental services, resource efficiency, biodiversity, low carbon technologies, renewable energy, the circular economy, waste management, management of food waste, and clean production technologies and business models related skills

Specific to the EII industrial ecosystem [84], there were **453 372 unique job advertisements** from companies in 2023 in the EU27. These job advertisements have been text-mined, and the required skills have been analysed from the perspective of the green transition. **The share of online job advertisements requiring skills related to the green transition in 2023 was 2%, which is rather low.** This implies that the job vacancies in the EII industrial ecosystem might not specify the requirements related to environmental skills but rather focus on the core skills required like processing or operating skills. In addition, obtaining green expertise could be done by educating inhouse or by acquiring companies that possess the required skill set.

The number of job advertisements with a requirement for green skills increased over time in particular from 2021 to 2022 (see Figure 16).

Figure 14: Number of online job advertisements with a requirement for environmental skills in EII



Source: Technopolis Group based on analysis of Cedefop data

[81] More information on the data sources, the approach taken, and the limitations of the data, is found in the methodological report.
[82] https://www.cedefop.europa.eu/en/tools/skills-online-vacancies This dataset covers the EU27 Member States (plus UK) and is based on the collection and analysis of more than 530 online job advertisement sources (424 distinct websites) which are open-access sites. The dataset provides information on most requested occupations and skills across European countries based on established international classifications, e.g., ISCO-08 for occupations, ESCO for skills, and NACE rev. 2 for sectors.
[83] This methodology has its limitations, as described in the methodological report. Some limitations are, for instance, that only online job advertisements are represented and that the volume and quantity of the data depend on the selection of portals and sources.
[84] In the case of the retail industrial ecosystem the dataset was filtered for the NACE industries as defined in the Annual Single Market Report.

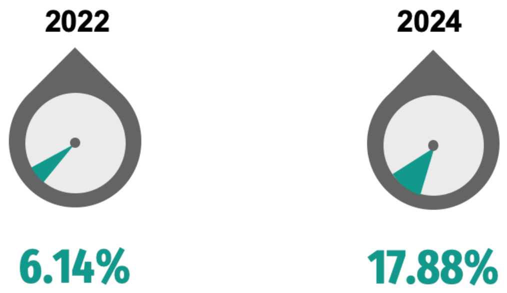
Skills supply

To gain insights into the supply of skilled professionals, LinkedIn has been used as data source. In particular, LinkedIn is the largest professional network platform with rich information like profile summary, job title, job description and field of study, which can be used for the identification of skilled professionals with skills relevant to the green transition. In order to capture the number of professionals working in the sector, occupations related to the industrial ecosystem have been taken into account. Green skills have been identified as skills related to biotechnology, renewable energy technologies, circular business models and clean production technologies.

A total of 2.56 million professionals were found to be related to the **chemical subindustry** on LinkedIn in April 2024. While this means that an estimated 31% of professionals in chemicals are active on the platform, it is to be noted that some jobs, functions and countries are better represented than others[85]. The data shows that about 51% of the chemical professionals active on LinkedIn has a master's degree, and 27% a bachelor's degree. Most professionals are active in Germany and France. In comparison to the demand, locations where the supply of professionals is comparatively high include Italy, Spain, and Romania.

17.9% of the registered professionals on LinkedIn employed in the chemical subindustry, **indicated to have one type of green skill in 2024**, which is a **significant increase** compared to 2022 where 6.1% were found to have at least one green skill (see Figure 17).

Figure 15: Share of professionals in chemicals with skills relevant for the green transition



Source: Technopolis Group based on LinkedIn

2.2.3. Demand for green products

EII industrial ecosystem

The transition pathway of the EII industrial ecosystem indicates that **consumer choices** have a decisive impact on driving the transformation towards a climate-neutral, circular economy, among other factors. Yet, it is challenging for EII to **convey the benefits of higher costs of products** that have lower environmental impact (e.g., greenhouse gas emissions) if benefits are only visible in the long run after purchase[86].

It is expected that public acceptance of higher costs for products with a lower carbon footprint—or higher costs for products with a larger footprint—will need careful consideration. If these costs become too elevated, they could negatively affect public support for climate action. Hence, understanding why people support or resist climate

[85] The methodological report outlines how the report corrects this representativeness bias, i.e., by comparing LinkedIn population to the active population and derive a corrective weighting.
[86] European Commission (2019) Masterplan for a competitive transformation of EU energy-intensive industries enabling a climate-neutral, circular economy by 2050. Retrieved from: https://data.europa.eu/doi/10.2873/854920

measures will be an important input among others to support the shaping of related policies[87].

Chemical subindustry

The EU continues to produce and consume large amounts of hazardous chemical substances that can pose health and environmental risks. While these chemicals are, at the same time, necessary to preserve food, protect us from fires and rain, safeguard crops, etc.

Evidence points out that consumers are increasingly **demanding safe and sustainable chemicals (or alternatives)**, such as packaging, cleaning products, pesticides, clothing, and personal care products. For instance, an international survey[88] found that, 87% of the consumers would prefer eco-friendly options over plastic products (e.g., recyclable plastics, biodegradable plastics, plant-based plastics, compostable plastics). EU continues its policies and regulations to limit, reduce and ban when possible the presence of hazardous substances in consumer products.

[87] European Commission (2019) Masterplan for a competitive transformation of EU energy-intensive industries enabling a climate-neutral, circular economy by 2050. Retrieved from: https://data.europa.eu/doi/10.2873/854920

[88] Accenture (2019) More than Half of Consumers Would Pay More for Sustainable Products Designed to Be Reused or Recycled, Accenture Survey Finds. Retrieved from: https://newsroom.accenture.com/news/2019/more-than-half-of-consumers-would-pay-more-for-sustainable-products-designed-to-be-reused-or-recycled-accenture-survey-finds

2.3. The impact of the industrial ecosystem on the environment

How is the industrial ecosystem's impact on the environment changing?

- The EII industrial ecosystem is traditionally known for its large environmental impact and its energy consumption. Although EIIs reduced their emissions significantly between 1990 and 2015 and continued improving thereafter, achieving climate neutrality by 2050 requires a **deeper commitment to sustainability.**

- The top four economies—Germany, France, Italy, and Spain—represent 63% of the EU's GDP and **generate more than half of the EU's greenhouse gas emissions from EII**.

- Total GHG emissions from the EU27 **chemical subindustry decreased 133 million tonnes** (CO_2) from 1990 to 2021, a decline of 52%. Nevertheless, since 2015 these emissions have **remained relatively stable** as overall production has increased over the period from 2015 to 2019, before falling again due to the COVID-19 pandemic and subsequent war in Ukraine.

- The chemical subindustry has played an important role in **strengthening energy efficiency**. In particular, improvements in energy efficiency and energy recovery in production processes have diminished the total energy consumption in the chemical and petrochemical subindustry. The EU27 energy consumption related to the chemical subindustry has **decreased with 20% since 1990**.

- The **generation of hazardous and non-hazardous waste in the EII industrial ecosystem increased** from 35.93 million tonnes in 2004 to 55.08 million tonnes in 2020. The volume of hazardous waste remains largely stable over the considered period, while the share of hazardous waste in the total waste in EU EII is decreasing.

The EII industrial ecosystem is traditionally known for its large environmental impact and its energy consumption. This section zooms in on select impact areas relevant for the **industrial ecosystem and/or the chemical subindustry** in particular and explores their environmental impact and performance and provides (long-term) trends in terms of several indicators, including greenhouse gas emissions, energy consumption, waste, and other indicators. In doing so, it builds on secondary data sources such as Eurostat and the European Environment Agency (EEA). Furthermore, this study reports on indicators developed through the Exiobase dataset. This dataset allows to measure the environmental impact of industrial ecosystems via the environmental impact of both production and consumption. More information on this dataset and the constructed indicators is provided in the methodological report.

Greenhouse gas emission and energy consumption

EII are a significant source of greenhouse gas emissions. The Commission Staff Working Document with scenarios for the EII transition pathway report that the EII industrial ecosystem **represents 22% of all EU greenhouse gas (GHG) emissions** in 2019[89]. Another study indicates that three sectors of the EII industrial ecosystem – non-metallic mineral products, basic metals, and chemical products – account for 63% of EII greenhouse gas emissions[90].

[89] European Commission (2021) Commission Staff Working Document. For a resilient, innovative, sustainable and digital energy-intensive industries ecosystem: Scenarios for a transition pathway. Retrieved from: https://ec.europa.eu/docsroom/documents/47059

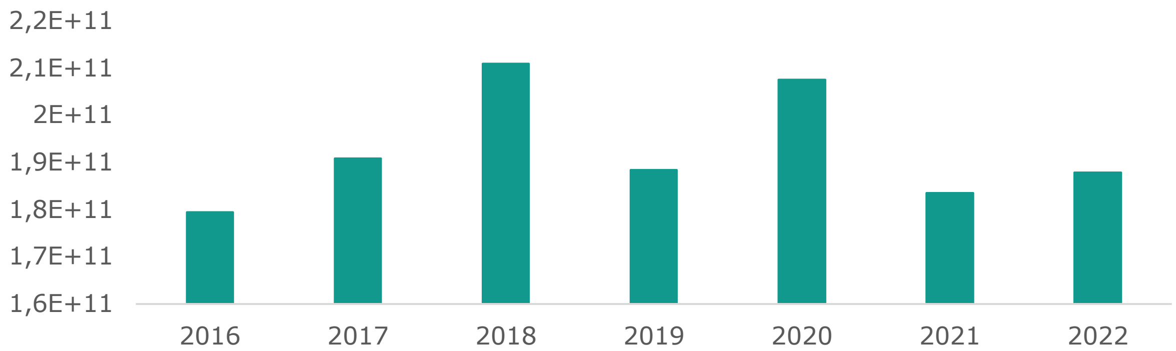
[90] European Commission (2022) ERA industrial technology roadmap for low-carbon technologies in energy-intensive industries. Retrieved from: https://data.europa.eu/doi/10.2777/92567

Although EIIs reduced their emissions significantly between 1990 and 2015 and continued improving thereafter, achieving climate neutrality by 2050 requires a **deeper commitment to sustainability**, including accelerated decarbonization and a circular economy. The industry's emissions must decrease by 23% by 2030 and by at least 95% by 2050 to meet the climate neutrality goals set in the European Climate Law.[91]

The ERA industrial technology roadmap for low-carbon technologies indicates that emissions from EIIs are linked to the GDP share of the Member States. The top four economies—Germany, France, Italy, and Spain—represent 63% of the EU's GDP and generate more than half of the EU's greenhouse gas emissions from the EII. In addition, according to Eurostat's energy balances, EII **consumed 83% of the final energy** used by EU industries in 2018[92].

Exiobase[93] provides additional insights into the greenhouse gas emissions of the EII industrial ecosystem in terms of its consumption and production account. Figure 18 shows that, when focusing on the consumption account, there were two peaks in CO_2 emissions in 2018 and 2020, and that there is again a slight increase in emissions from 2021 to 2022. This rise can be associated with period of increased consumption, and points towards the difficulties associated with deploying technologies aimed at reducing greenhouse gas emissions at full scale and the need to devote sufficient attention to funds supporting the deployment of technologies. When focusing on the production account, Figure 19 shows that from 2019 onwards, the CO_2 emissions are increasing. In general, the figures display that the bulk of CO_2 emissions comes from production, rather than consumption for the EII industrial ecosystem, which is associated with the production-driven nature of the ecosystem itself.

Figure 16: Greenhouse gas emissions of the EII industrial ecosystem (CO_2 emissions in megatons) - consumption account



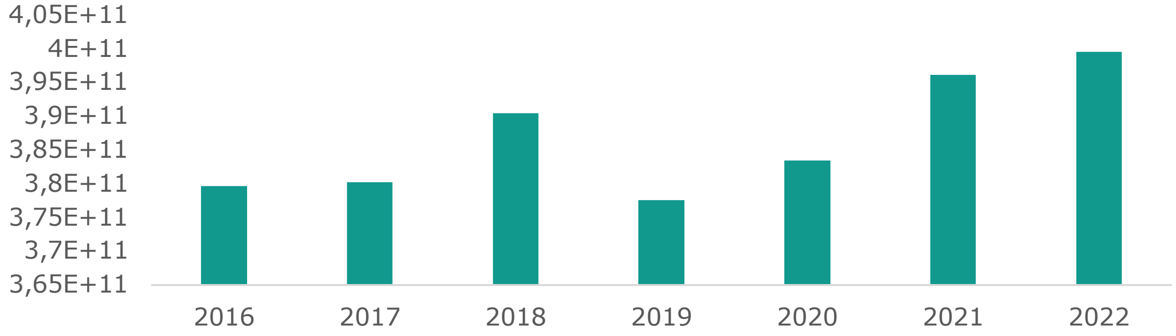
Source: Technopolis Group based on Exiobase

[91] European Commission (2021) Commission Staff Working Document. For a resilient, innovative, sustainable and digital energy-intensive industries ecosystem: Scenarios for a transition pathway.

[92] European Commission (2022) ERA industrial technology roadmap for low-carbon technologies in energy-intensive industries. Retrieved from: https://data.europa.eu/doi/10.2777/92567

[93] About Exiobase. Retrieved from: https://www.exiobase.eu/index.php/about-exiobase

Figure 17: Greenhouse gas emissions of the EII industrial ecosystem (CO_2 emissions in megatons) - production account



Source: Technopolis Group based on Exiobase

The European Environment Agency (EEA) announced that the total GHG emissions from the EU27 **chemical subindustry decreased 133 million tonnes** (CO_2) from 1990 to 2021, a decline of 52% (Figure 20)[94]. Nevertheless, since 2015 these emissions have **remained relatively stable** as overall production has increased over the period from 2015 to 2019, before falling again in lieu of the COVID-19 pandemic and subsequent war in Ukraine[95].

The EEA notes that the general reduction in emissions is mainly driven by the reduction of process emissions, the decrease of nitrous oxide, and fluorinated gases emissions[96], however further process emission reductions are considered difficult to abate as these are related to the underlying feedstock which is largely based on carbon for chemicals products. Energy combustion emissions do have the potential for further abatement through the transition towards electrification and the update of especially green hydrogen by the subindustry. The EEA indicator on total GHG emissions is one of the indicators for the twin transition as identified in the 2023 Annual Progress Report of the transition pathway of the chemical subindustry[97].

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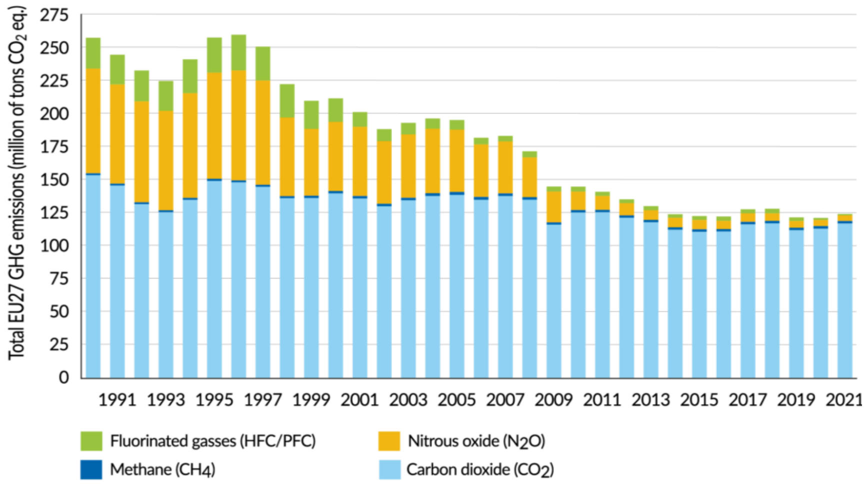
[94] CEFIC (n.d.) Environmental performance. Retrieved from: https://cefic.org/a-pillar-of-the-european-economy/facts-and-figures-of-the-european-chemical-industry/environmental-performance/

[95] CEFIC (2025) Growth and competitiveness. Retrieved from: https://cefic.org/a-pillar-of-the-european-economy/facts-and-figures-of-the-european-chemical-industry/growth-and-competitiveness/#h-eu27-chemical-industry-production

[96] CEFIC (n.d.) Create Low-Carbon Economy. Retrieved from: https://cefic.org/a-solution-provider-for-sustainability/cefic-sustainable-development-indicators/create-low-carbon-economy/

[97] European Commission (2024) 2023 annual progress report – Transition pathway for the chemical industry. Retrieved from: https://data.europa.eu/doi/10.2873/78547

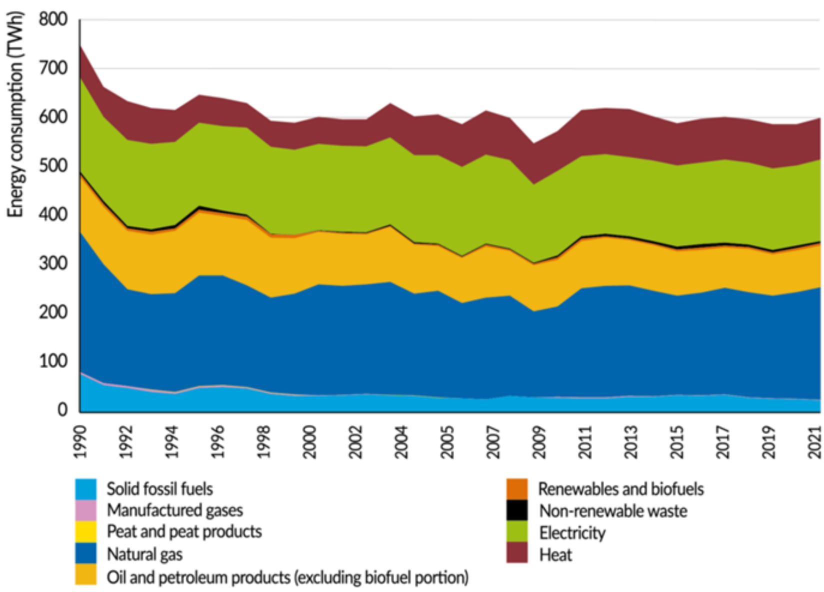
Figure 18: Total scope 1 GHG emissions per type of GHG by the EU27 chemical subindustry



Source: CEFIC based on EEA

The chemical subindustry has played an important role in strengthening energy efficiency. In particular, improvements in energy efficiency and energy recovery in production processes have diminished the total energy consumption in the chemical and petrochemical subindustry. Figure 21 shows that the EU27 energy consumption has decreased with 20% since 1990[98,99]. Natural gas and electricity are the primary energy sources, accounting for 38% and 28% respectively in 2021. Energy consumption from solid fossil fuels was relatively low in 1990 and decreased further by 69% over the period of 1990-2021. The energy consumption by source is one of the indicators for the twin transition as identified in the 2023 Annual Progress Report of the transition pathway of the chemical subindustry[100].

Figure 19: Energy consumption by the EU27 chemical subindustry



Source: CEFIC based on Eurostat

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[98] CEFIC (n.d.) Energy Consumption. Retrieved from: https://cefic.org/a-pillar-of-the-european-economy/facts-and-figures-of-the-european-chemical-industry/energy-consumption/

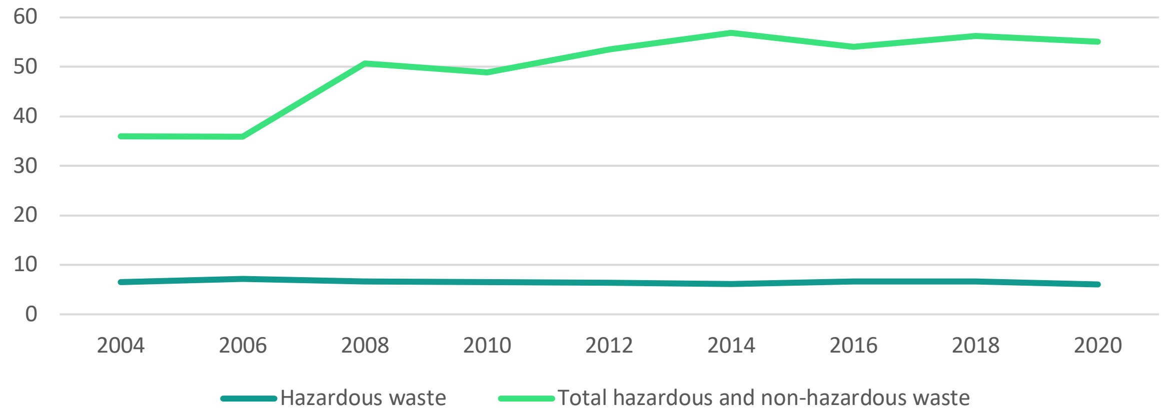
[99] CEFIC (n.d.) Create Low-Carbon Economy. Retrieved from: https://cefic.org/a-solution-provider-for-sustainability/cefic-sustainable-development-indicators/create-low-carbon-economy/

[100] European Commission (2024) D2023 annual progress report – Transition pathway for the chemical industry. Retrieved from: https://data.europa.eu/doi/10.2873/78547

Waste

The generation of waste is an important environmental indicator in the **EII industrial ecosystem**. Eurostat data shows that the **generation of hazardous and non-hazardous waste in the EII industrial ecosystem** (based on NACE codes) **increased** from 35.93 million tonnes in 2004 to 55.08 million tonnes in 2020 (see Figure 22). In 2020, the generation of waste fell slightly compared to 2018, likely due to the COVID-19 pandemic. The volume of hazardous waste remains largely stable over the considered period, while the share of hazardous waste in the total waste in EU EII is decreasing.

Figure 20: Waste generation in the EII industrial ecosystem in the EU27 (2012-2020)

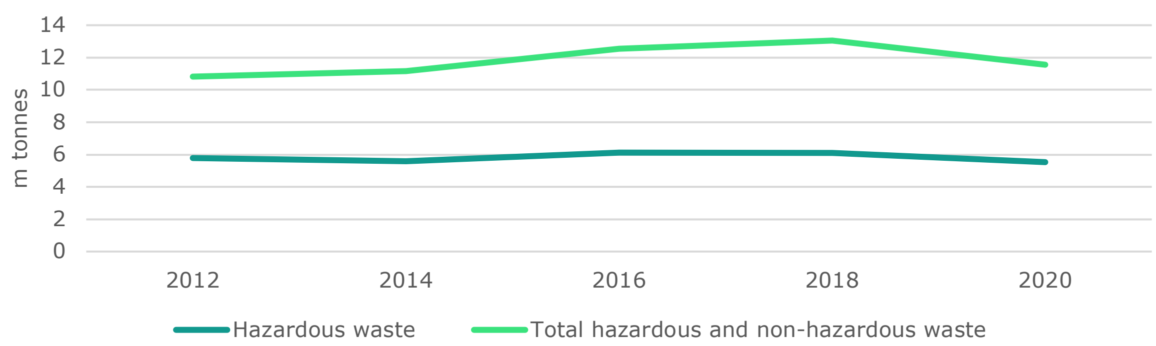


Note: NACE codes included are: C16, C17-C18, C19, C20-22, C23, C24-25. As C18 and C25 are not in the definition of NACE codes for the EII industrial ecosystem but included in this figure, the numbers presented here are overestimations.

Source: IDEA Consult based on Eurostat (env_wasgen)

The generation of both hazardous and non-hazardous waste in the **chemical subindustry** in the EU increased by 21% between 2012 and 2018 (see Figure 23). In 2020, waste generation fell by 11% compared to 2018, most likely temporarily due to the COVID-19 pandemic[101]. Zooming in on the waste categories, the share of total generated hazardous waste remained stable at about 50%, or 5.8 million tonnes per year, between 2012 and 2020.

Figure 21: Waste generation in the chemical subindustry in the EU27 (2012-2020)



Source: IDEA Consult based on European Environment Agency (EEA)

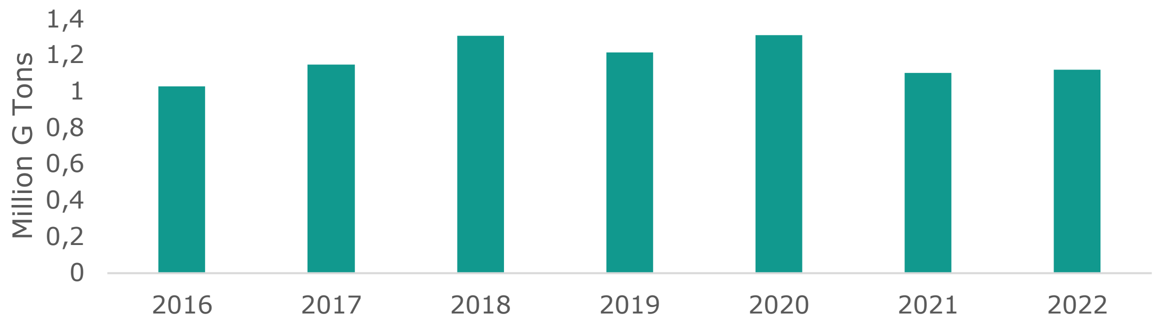
[101] EEA (2024) Waste generation in the chemical industry (Indicator). Retrieved from: https://www.eea.europa.eu/en/european-zero-pollution-dashboards/indicators/waste-generation-in-the-chemical-industry

Other environmental impact

The Exiobase indicators provide further insights into the impact of the EII industrial ecosystem on the environment:

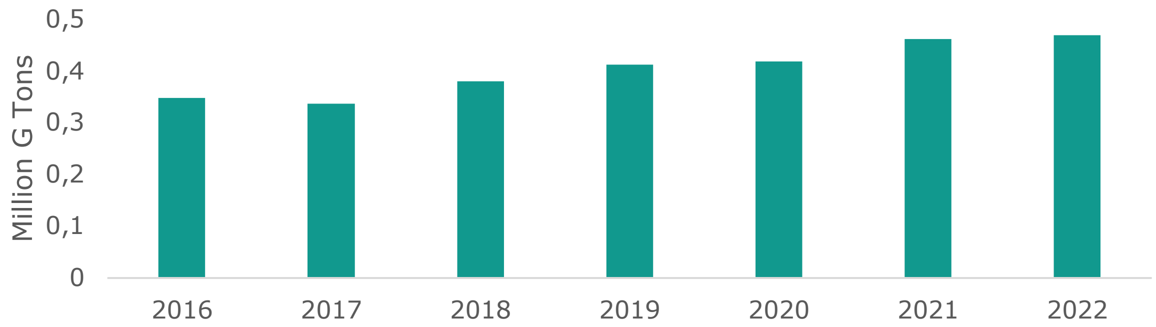
The amounts of used and unused materials[102] (**material extraction**) for the consumption and production related to the EII industrial ecosystem follow a similar trend as compared to that of CO_2 emissions, with evident, yet less amplified, peaks in 2018 and 2020. The two elements are interrelated with the notion that also increased material extraction can lead to increases in resulting emissions and other environmental impacts. The trend in consumption is rather stable in 2021 and 2022, creasing from 2020 as a result of the COVID-19 pandemic (see Figure 24). The trend in production follows a continuing increasing trend with global figures lower than the consumption material extraction (see Figure 25).

Figure 22: Material extraction of the EII industrial ecosystem (in million G tons) – consumption account



Source: Technopolis Group based on Exiobase

Figure 23: Material extraction of the EII industrial ecosystem (in million G tons) – production account

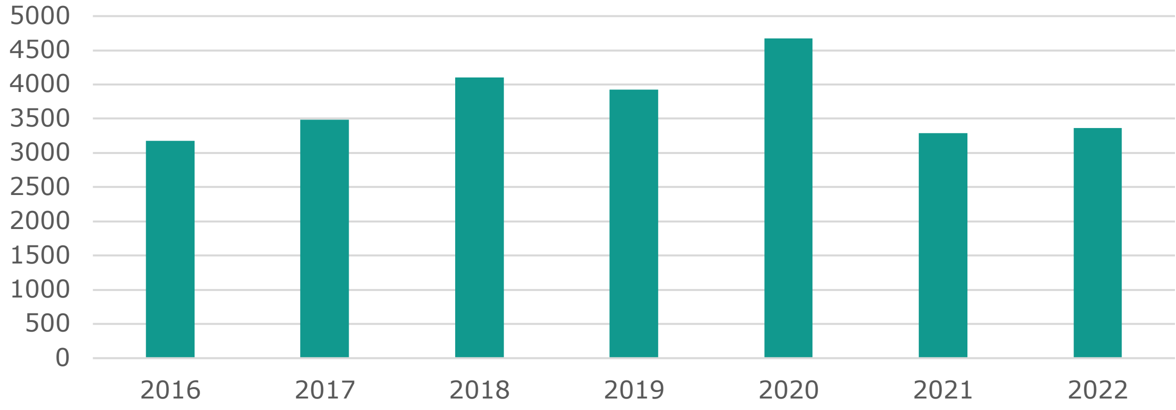


Source: Technopolis Group based on Exiobase

Furthermore, **water** is a key input for the EII industrial ecosystem. The total water consumption of the EII industrial ecosystem has decreased in 2021 and 2022 compared to 2020 when considering EU EII consumption, which is largely attributed to overall decreases in production as reported across various subindustries. Small peaks are however visible in 2018 and 2020 which align with years of increased consumption and thus also increased environmental impact across several indicators (see Figure 26). The water consumption for EII production in the EU is increasing over the last years, following on also from a more global picture on increasing environmental impact across several indicators for the EII industrial ecosystem in related to production accounts (see Figure 27).

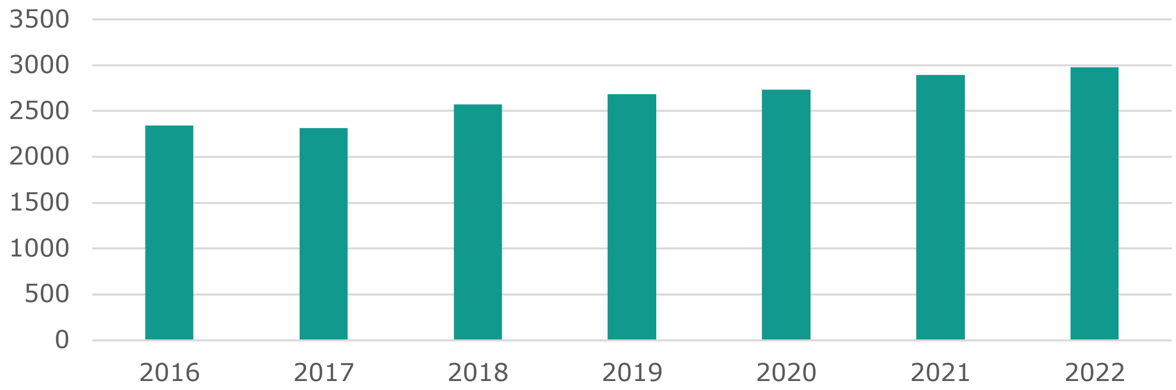
[102] The methodological report outlines that these materials include used and unused crops and crops residue, grazing and fodder, forestry and timber, fisheries, non-metallic minerals, iron ore, non-ferrous metal ores, coal and peat, and oil and gas.

Figure 24: Water consumption of the EII industrial ecosystem (in million m³) – consumption account



Source: Technopolis Group based on Exiobase

Figure 25: Water consumption of the EII industrial ecosystem (in million m³) – production account



Source: Technopolis Group based on Exiobase

3. Digital transition

3.1. Industrial efforts into the digital transition

What is the progress of industrial efforts towards digitalisation?

- The share of digital related patenting activities in the EII industrial ecosystem lies **between 7 and 9%**. These relatively lower values can be explained by the fact that patents supporting the digital transition may be rather developed in other industrial ecosystems.

- **24% of companies had a concrete strategy in place for digital transformation** in the EII industrial ecosystem in 2024.

- **The EMI Enterprise Survey revealed an increase in the uptake of digital technologies like** Cloud, Internet of Things, Artificial Intelligence, and Robotics technologies. - 62% of businesses that adopted AI did so within the past three years. **20.5% of companies use AI in the marketing and sales,** followed by 17% in product/service design**.** Several AI applications are rapidly evolving in the chemical subindustry, especially in product design, more effective replacement of hazardous materials, AI-driven predictive toxicology, enhancing predictive maintenance, and optimisation in production operations and inventory decisions.

- Digital technology startups are increasingly influencing the chemical subindustry by introducing innovative solutions that **enhance efficiency, sustainability, and competitiveness**. These startups focus on various areas, including advanced chemical manufacturing, data analytics, artificial intelligence and digital platforms. Digital startups lie mainly in the area of **AI and big data** for the period 2015 to 2022.

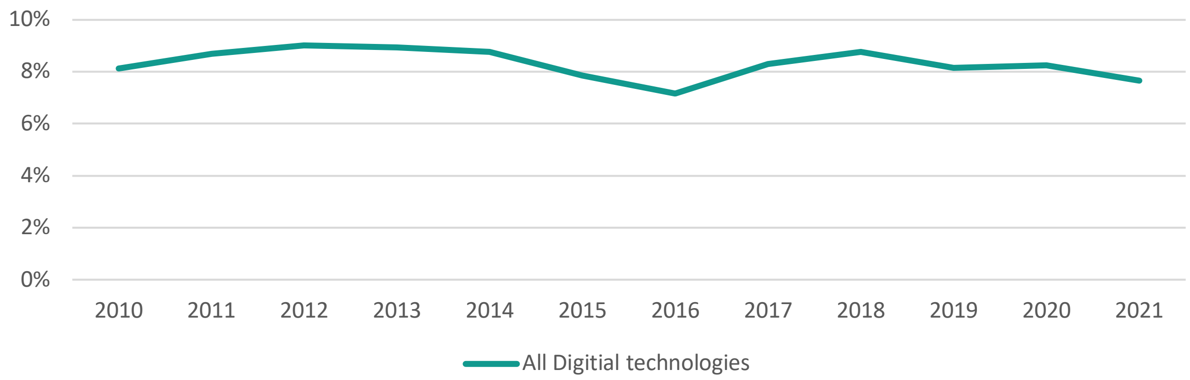
- **The vast majority of EII companies invest less than 5% of their annual turnover into digital technologies**. Technologies attracting between 6-10% of annual turnover include AR/VR, Big data, Blockchain, IoT and AI.

3.1.1. Technology generation

Technology generation in terms of patents for the digital transition in the EII industrial ecosystem represent a complementary picture to those patenting activities highlighted under the green transition chapter above.

The share of digital transition-related patent activities of the EII industrial ecosystem relative to other industrial ecosystems in the EU 27 is presented in Figure 26. The values are relatively stable over the period of observation from 2010 to 2021, with a downward trend from 2014 to 2016, followed by an increasing trend towards 2018 and a relative decline thereafter until 2021. Overall values remain in the area of 7% to 9%. Patenting activities related to digital technologies may be developed in other industrial ecosystems, and applied to the EII where relevant, such as those related to AI.

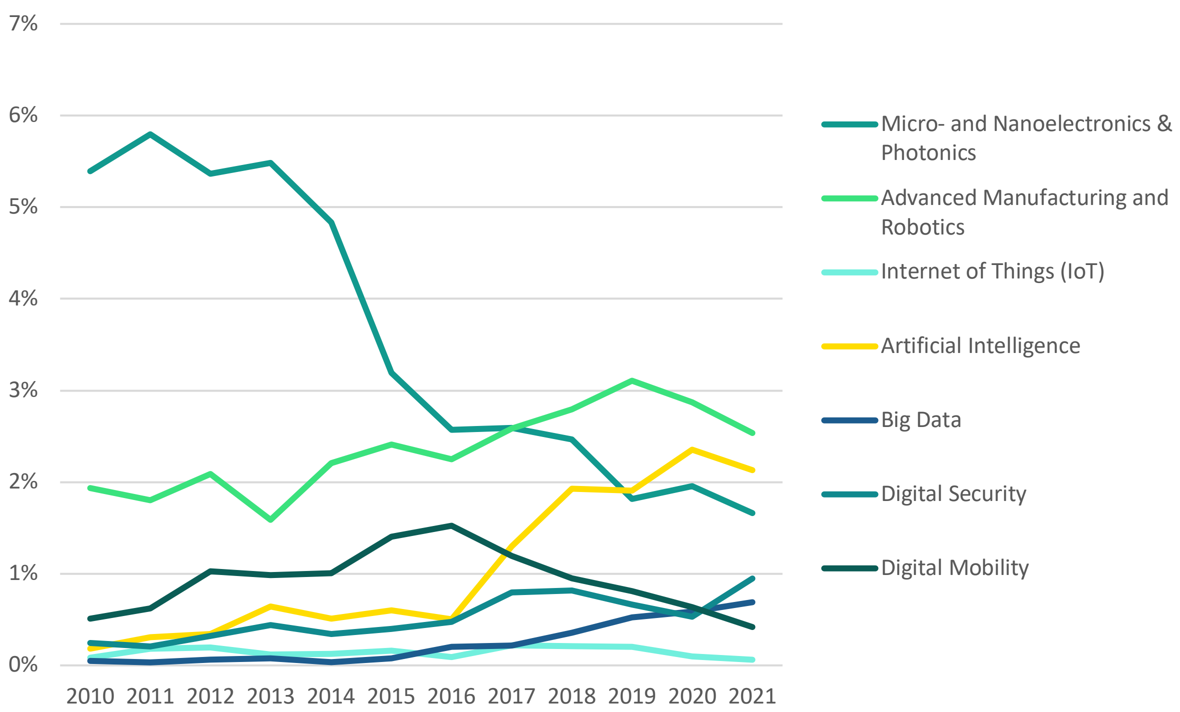
Figure 26: Share of digitalisation-related patents in the EII industrial ecosystem in all patents filed in EU27 industrial ecosystems



Source: Fraunhofer based on PATSTAT

In terms of the underlying digital technologies, patenting in micro- and nanoelectronics and photonics was the leading digital technology until 2016, reaching a maximum of 5.8% in 2017, at which point advanced manufacturing and robotics took over this leading position until 2019 (see Figure 27). From 2020, AI and big data are the leading digital transition technology for patents in EII on upward trend from 2014 onwards. Digital mobility and security were also an important technologies in terms of digital transition patents in the EII industrial ecosystem with a decline from 2016 and 2018, respectively.

Figure 27: Share of respective digital transition technologies in overall patents filed in the EII industrial ecosystem



Source: Fraunhofer based on PATSTAT

3.1.2. Uptake of digital technologies

The targets of the Digital Compass set in relation to digital transformation of businesses are dedicated to help **late digital technology adopters** – more than 90% of SMEs to reach at least a basic level of digital intensity[103]. Looking at the EII industrial ecosystem, based on the definition that is outlined in NACE, a diverse picture of digitalisation emerges across the various subindustries (see Table 1)[104]. Especially wood and paper, rubber & plastic and the metals subindustries are dominated by a very low digital intensity index, with all EII subindustries having the largest share of their companies either with a very low or low digital intensity index. While the share of enterprises with a very low and low level of digital intensity is on the decline across the EII, the share of enterprises with a high and very high level of digital intensity is generally on the rise for all subindustries between 2021 and 2023 (apart from coke and petroleum). Likewise, the number of enterprises with at least a basic level of digitalisation intensity is on the rise across the subindustries wood and paper, chemicals, rubber and plastic as well as metals.

Table 1: Digital intensity of EII industrial ecosystem enterprises (percent)[105]

	Wood and paper (C16-18)		**Coke and petroleum (C19)**		**Chemicals (C20)**		**Rubber and plastic (C22-C23)**		**Metals (C24-C25)**	
	2021	2023	2021	2023	2021	2023	2021	2023	2021	2023
Enterprises with very low digital intensity index	**52.3**	**48.8**	26	**39.8**	26.4	22.5	**49.2**	**44**	**52.8**	**49.7**
Enterprises with low digital intensity index	32	34.2	**38.5**	32.8	**39.6**	**36.3**	34.1	35.4	34.9	35.9
Enterprises with high digital intensity index	13.3	14.3↑	28.1	23	28	32.8↑	14.7	17.6↑	11.2	12.7↑
Enterprises with very high digital intensity index	2.3	2.8↑	12.6	11.5	6	7.8↑	2.1	3↑	1.1	1.7↑
Enterprises with at least basic level of digital intensity	*47.7*	*51.2*↑	*77.1*	*62*	*73.6*	*77.5*↑	*51.8*	*56*↑	*47.2*	*50.3*↑

Source: IDEA Consult based on Eurostat [isoc_e_diin2]

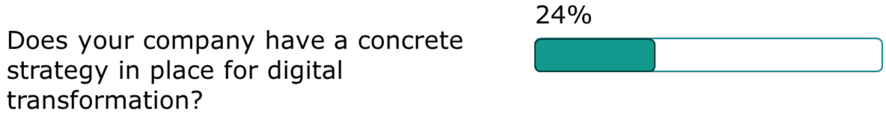
Despite these ambitious targets, according to the EMI survey 2024 results, **only 24% of companies have a concrete strategy in place for digital transformation in the EII industrial ecosystem** (see Figure 28).

[103] European Commission (n.d.) Europe's Digital Decade: digital targets for 2030. Retrieved from: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en

[104] Eurostat (2024). Digital Intensity by NACE Rev.2 activity. Retrieved from: https://ec.europa.eu/eurostat/databrowser/view/isoc_e_diin2__custom_13346345/default/table?lang=en

[105] EII defined by the following subsection of NACE sectors: C16-C18 manufacture of wood, paper, printing and reproduction; C19 manufacture of coke and refined petroleum products; C20 manufacture of chemicals and chemical products; C22-C23 manufacture of rubber and plastic products and other non-metallic mineral products; C24-C25 manufacture of basic metals and fabricated metal products, except machinery and equipment

Figure 28: Share of companies in the EII industrial ecosystem that has adopted a strategy for the digital transformation



Source: EMI Survey 2024

In 2023, cloud and big data were the leading technologies, however in 2024 the landscape of digital technology adoption for the EII industrial ecosystem has shifted towards **Cloud, Internet of Things, Artificial Intelligence, and Robotics**, as depicted in Figure 29.

Figure 29: Share of businesses in the EII industrial ecosystem that have adopted digital technologies

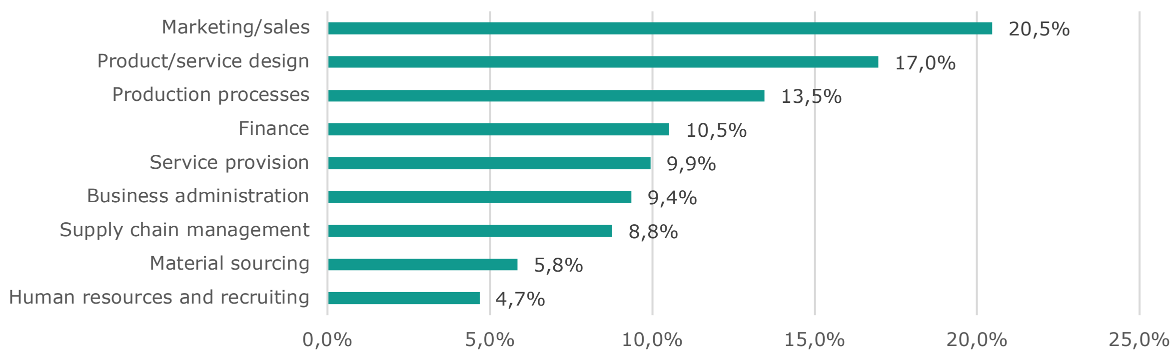
Digital Technologies	***Share of adoption (2023)***	***Share of adoption (2024)***
Cloud	**29.1%**	**37.1%**
Internet of Things	11.1%	**27.6%**
Artificial Intelligence	12.7%	**25.7%**
Robotics	9.3%	**18.6%**
Big Data	14.0%	16.2%
Augmented and Virtual Reality	6.6%	4.3%
Blockchain	4.8%	7.6%
Edge Computing		7.1%

Source: EMI Enterprise Survey, 2024

Adoption of Artificial Intelligence

The growing volume of accessible data has the potential to significantly enhance the capability of AI algorithms. AI technology can offer innovative solutions ranging from predictive analytics and maintenance as well as process optimisation. The survey of companies in the EII industrial ecosystem indicates that **62% of EII businesses that have adopted AI have done so within the last three years**. In terms of business operation stage, 20.5% of companies use AI in marketing and sales as depicted in Figure 30, followed by 17% in product/service design. 26% of EII businesses develop AI systems in house and 40% of EII businesses use AI systems via external service providers, whereby 11% indicate that the AI used is provided by US service providers.

Figure 30: Share of EII companies using AI according to the business operation stage



Source: EMI Enterprise Survey, 2024

A recent CEFIC study[106] shows that AI is employed throughout the value chain in the **chemical subindustry**. The CEFIC survey reveals that over 60% of chemical companies are currently in the pilot or early adoption phase. The survey also shows that AI capabilities have the potential to improve every aspect of the chemical value chain and contribute significantly to attaining sustainability objectives. Currently, several AI applications are rapidly evolving in the chemical subindustry, especially in product design, allowing smarter solutions to be brought to the market faster, more effective replacement of hazardous materials, AI-driven predictive toxicology, enhancing predictive maintenance, and optimisation in production operations and inventory decisions.

Advanced manufacturing and robotics

Advanced manufacturing and robotics technologies include those related to process technologies, especially in production, related to underlying equipment and procedures used in manufacturing, also in an automated way. Industrial automation enables access to real-time data, aiming to optimise production processes, enhancing energy and resource efficiency, and facilitating more informed decision-making. Advanced manufacturing and robotics include the application of autonomous and dexterous robots that can potentially provide access to remote raw material deposits and improve occupational health and safety[107]. In the chemical subindustry, robotics and automation enable a safer, more productive industry, that can also contribute to sustainability objectives. Moreover, they allow for the elimination of dangerous activities otherwise performed by humans, areal inspections (through drones), safety inspections of sensitive grounds, chemical tank cleaning, and they can improve the consistency of lab experiments. The CEFIC survey[108] elucidates that around 35% of companies in the chemical subindustry have already been automating certain workflows and supporting their workers with robotic systems.

Internet of Things

Internet of Things (IoT) is a digital technology that refers to the use of smart and interconnected devices that collect data and information through sensors and transmit these using an internet connection. IoT presents an opportunity to gather information about ongoing processes and inform decision making either through a software-based solution or with the support of an artificial intelligence solution. Specifically in the chemical subindustry, IoT is currently used by 25% of chemical companies, and the uptake is expected to increase to 40% in the coming years[109], with the main applications in production, logistics and distribution. In logistics processes, IoT solutions seem to be commonly used to ensure the right transportation conditions (e.g., temperature, humidity), facilitate real-time tracking and monitoring of the transported goods, and bring more transparency to the communication process. Also, in supply chain management and optimisation, IoT is applied by, for instance, tracking and monitoring of raw materials and products, and bringing more precision in planning. Regular flows of data from connected IoT sensors are also exploited to supervise products throughout their lifecycle.

Digital tech startups specialised in the chemical subindustry

A total of **419 companies were identified related to the chemical subindustry** as part of the EII industrial ecosystem in analysing the Crunchbase and Net Zero Insights data. Globally, numbers of startups related to the advanced digital technologies as identified in the methodological framework remain low compared to more basic digital technologies. Of these, 30 startups were created in relation to the digital transition between 2015 and 2023.

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[106] Arthur D. Little & CEFIC (2023) Digital Technologies for Sustainability in the European Chemical Industry. Retrieved from: https://cefic.org/app/uploads/2023/04/ADL_CEFIC_Digital_technologies_for_sustainability_2023.pdf

[107] European Commission (2021) Commission Staff Working Document. For a resilient, innovative, sustainable and digital energy-intensive industries ecosystem: Scenarios for a transition pathway. Retrieved from: https://ec.europa.eu/docsroom/documents/47059

[108] Arthur D. Little & CEFIC (2023) Digital Technologies for Sustainability in the European Chemical Industry.

[109] Arthur D. Little & CEFIC (2023) Digital Technologies for Sustainability in the European Chemical Industry.

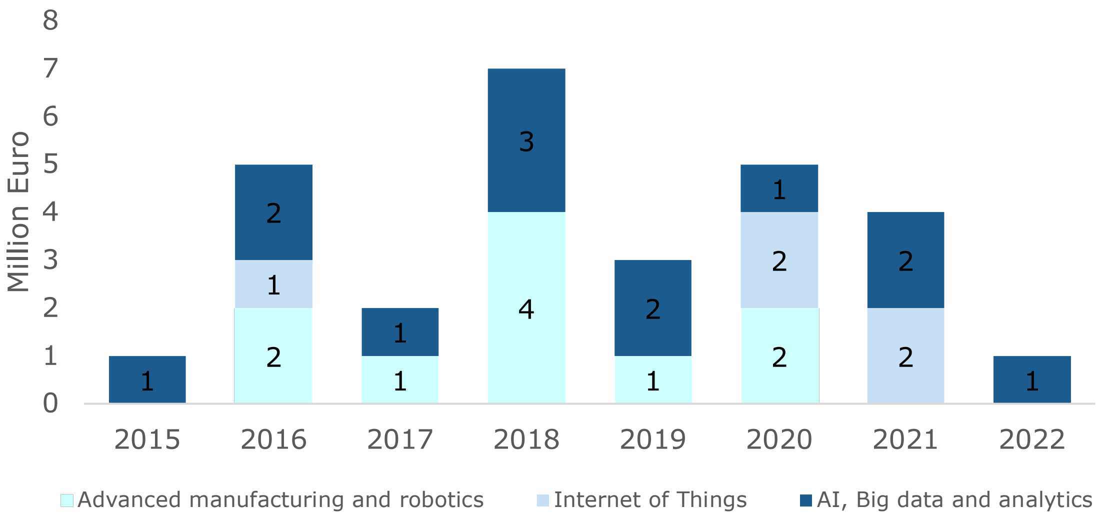
Zooming in on the relation to the underlying digital technologies related to the chemical subindustry, the development of digital startups lie mainly in the area of **AI and big data** (N=13) for the period 2015 to 2022(see Figure 31).

Examples of **AI startups** in the chemicals subindustry include:

- The **ExoMatter Materials Platform**[110] generates a personalised shortlist of the most suitable materials for industrial applications. Drawing on materials data from numerous scientific sources, it is utilising AI and allows to apply a wide range of multidimensional physical, chemical and engineering criteria as well as sustainability attributes and anticipated cost.
- **Quantistry**[111] offers chemical simulations, powered by quantum chemistry and machine learning. The cloud-based solution gives customers a significant competitive advantage by simplifying and accelerating the development of chemical, materials science and pharmaceutical products.
- **Nextmol**[112] is a Barcelona-based startup specialised in computational chemistry. It develops a software platform to accelerate the design of new chemicals through molecular modelling and artificial intelligence for a more efficient R&D. Nextmol shortens the path to chemical innovation over the traditional lab approach thanks to its ability to perform unlimited testing via computations. Furthermore, computations provide key insights about the physico-chemical behaviour of the candidate molecules.

Further technologies in which chemicals subindustry startups specialise related to the digital transition include advanced manufacturing and robotics, with a total of 10 startups founded in the period of 2015 to 2022, as well as Internet of Things with 5 startups founded over the same period.

Figure 31: Technologies underpinning digital tech startups in the chemical subindustry



Source: Technopolis Group based on Crunchbase and NO

Digital technology startups are increasingly influencing the chemical subindustry by introducing innovative solutions that enhance efficiency, sustainability, and competitiveness. These startups focus on various areas, including **advanced chemical manufacturing, data analytics, artificial intelligence and digital platforms**. They also influence the chemical subindustry ecosystem by offering customised software solutions for smart chemical manufacturing such as computer-aided engineering, machine

110 https://www.exomatter.ai/en/
111 https://www.quantistry.com/
112 https://www.nextmol.com/

learning, digital twin technologies, sensor networks, and big-data analytics, all aimed at optimising production processes and improving operational efficiency.

3.1.3. Private investments

Investments play a central role in digitizing the EII industrial ecosystem, while at the same time supporting the green transition through the availability of information and analytics. Investment intensity on the EU market depends on the subindustry under consideration, where especially the competitiveness of the cement industry is under pressure on the medium term from non-EU competitors due to a high investment intensity related to the cost of decarbonisation. As a result, the pressure from high investment intensity results in the reduced attractiveness of private investments in the European EII[113].

Different types of private investments are explored based on the available datasets, including private investments made by companies themselves, as well as investments attracted by young companies through venture capital investments.

The EMI survey 2024 captured insights on company spending related to the digital transition, whereby the **vast majority of EII companies indicate that less than 5% of their annual turnover goes towards investments in digital technologies**. The Figure below showcases the breakdown of the share of EII respondents who indicated if they make investments in specific advanced digital technologies in the EII industrial ecosystem. EII companies are **predominantly investing less than 1% of their annual turnover in digital technologies** such as AI and big data, as well as Internet of Things and Robotics. Select technologies such as robotics are predominantly attracting 1 to 5% of annual turnover. Technologies attracting between 6-10% of annual turnover include AR/VR, Big data, Blockchain, IoT and AI.

Figure 32: investment of companies in EII in digital technologies

	Cloud	**Robotics**	**IoT**	**Big Data**	**Artificial Intelligence**	**AR/VR**	**Blockchain**
Less than 1% of annual turnover	49%	13%	47%	48%	59%	28%	30%
1-5% of annual turnover	49%	50%	19%	20%	18%	14%	30%
6-10% of annual turnover			7%	10%	4%	14%	10%
11-30% of annual turnover							
More than 30% of annual turnover							

Source: EMI Enterprise Survey 2024

Of the global venture capital investments that take place, only 18% are invested in Europe, compared to roughly 50% that go to the US[114]. In addition, fragmented capital markets further limit investments, and, as a result, there is an overreliance on outside investment

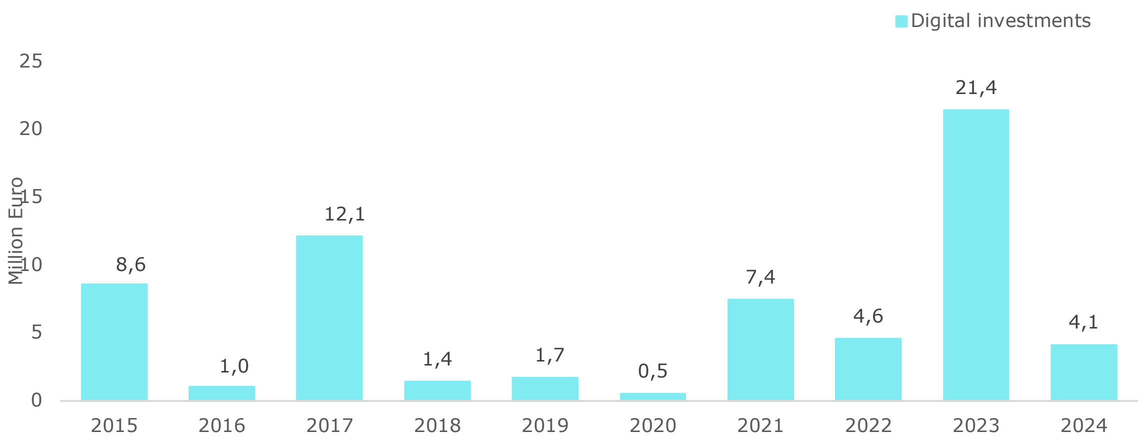
[113] ERT (2024) Competitiveness of European Energy-Intensive Industries. Retrieved from: https://ert.eu/wp-content/uploads/2024/04/ERT-Competitiveness-of-Europes-energy-intensive-industries_March-2024.pdf
[114] ERT (2024) Competitiveness of European Energy-Intensive Industries. Retrieved from: https://ert.eu/wp-content/uploads/2024/04/ERT-Competitiveness-of-Europes-energy-intensive-industries_March-2024.pdf

(e.g. from the US). This particularly affects scaleups in their ability to grow due to the limited resources to support their growth[115].

Venture capital investments are tracked in the Crunchbase and NetZero Insights data set, which gives insights into venture capital investments in young companies (age 10 years or less) related to the digital transition as well as the investments related to the technologies underpinning the transition, where notably AI and big data stands out in this regard.

Zooming in on the chemical subindustry, a total of **EUR 62.9 m is related to the digital transition of chemical young companies between 2015 and 2023** (see Figure 33), with a notable peak of investment in 2023.

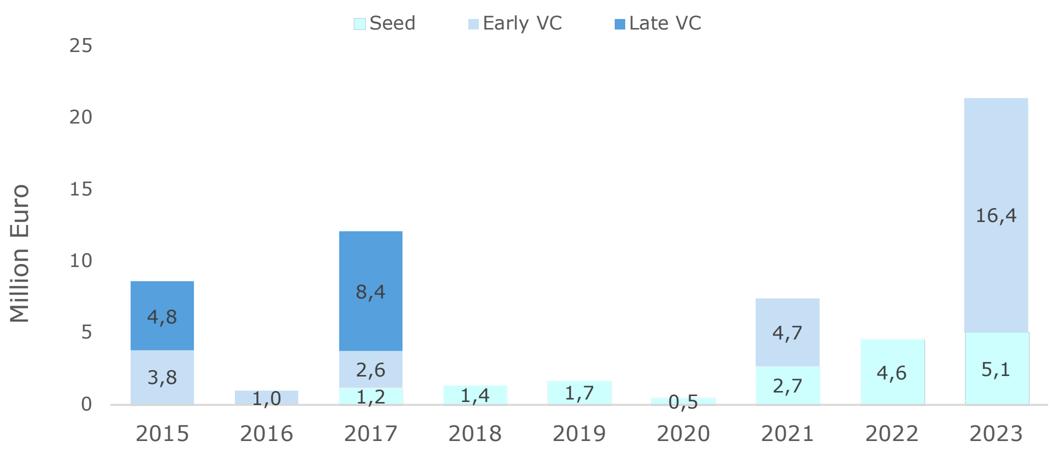
Figure 33: Venture capital investment into chemical young companies – digital transition



Source: Technopolis Group based on Crunchbase and NO

In terms of investment phase, venture capital investments in relation to the digital transition are largely attributed to **early VC funding**, with a total of **EUR 28.5 m** allocated between 2015 and 2023.

Figure 34: Venture capital investments stages into digital transition of chemical startups



Source: Technopolis Group based on Crunchbase and NO

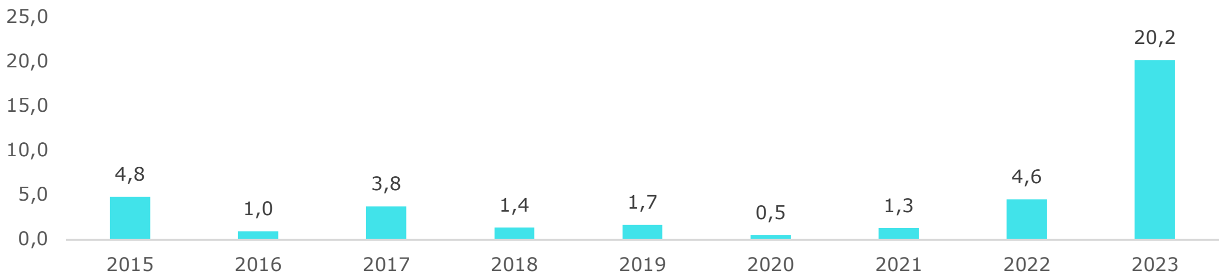
Venture capital investments into the digital transition of chemical young companies are dominated by **AI and big data related investments**, with a total of **EUR 39.3 m in**

[115] EIB (2024). Investment report 2023/2024: Transforming competitiveness. Retrieved from: https://www.eib.org/en/publications/online/all/investment-report-2023-2024.htm

investments between 2015 and 2023. Details on the funding rounds of select **young companies in the AI and big data technology** include:

- **c-Lecta**[116] (AI and big data) is a German company that was founded in 2004 that develops products for food, pharma and chemical industries based on enzymes. The company was acquired by KERRY group in 2022 for EUR EUR 137 m.
- **Iktos** (AI and big data, advanced manufacturing technology and robotics) is a French deep learning technology platform focused on new drug design and discovery that was founded in 2016. The company raised EUR 15 million in 2023 through a series A funding round.
- **APIX Analytics**[117] (AI and big data) is a French company founded in 2014 that develops a gas chromatograph based on miniaturisation to bring sampling onsite. APIX Analytics raised a total of EUR 15 m through four funding rounds between 2015 and 2022.

Figure 35: Venture capital investments stages into AI of chemical startups



Source: Technopolis Group based on Crunchbase and Net Zero Insights

[116] https://www.c-lecta.com/
[117] https://apixanalytics.com/

3.2. Framework conditions – assessment of the broader industrial ecosystem supporting the digital transition

To what extent do framework conditions such as public financing and skills support the digital transition?

- The analysis shows that about **11% (or EUR 1.14 bn) of the funding to EII ERDF projects** supported the digital transition. In terms of **number of ERDF projects, 16%** is contributing to the digital transition (or 1 399 projects)

- The analysis of the CORDIS data demonstrates that the Horizon 2020 programme provided EUR 302.5 million to projects classified under the EII industrial ecosystem[118]. Horizon Europe thus far[119] provided EUR 229.2 million to EII projects.

In Horizon 2020, **36.7% of the funding to EII projects contributed to the digital transition**. In Horizon Europe, **28.4% of the funding** to date contributes to EII projects related to the digital transition.

- There were **2.56 million professionals registered in the chemical subindustry on LinkedIn in April 2024.** Within these registered professionals, **11.29% indicated to have one type of digital skill** in 2024, which is an increase from 2022 where **10.42%** were found to have at least one digital skill.

- The total number of **online job advertisements** in the EII industrial ecosystem **amounted to 139 863 in 2023** in the EU27. The results of the data analysis show that **12% of the job advertisements** included a requirement of **advanced digital skills such as AI, big data, augmented and virtual reality, or cloud.**

3.2.1. Public investments supporting the digital transition

This study examines the **public investments supporting the digital transition in the EII industrial ecosystem.** The public investment sources analysed are the Cohesion policy, and in particular the European Regional Development Fund (ERDF), and the Framework Programmes, Horizon 2020 and Horizon Europe.

Cohesion policy

A key source of public funding that enables the digital transition is the **European Regional Development Fund[120]**.

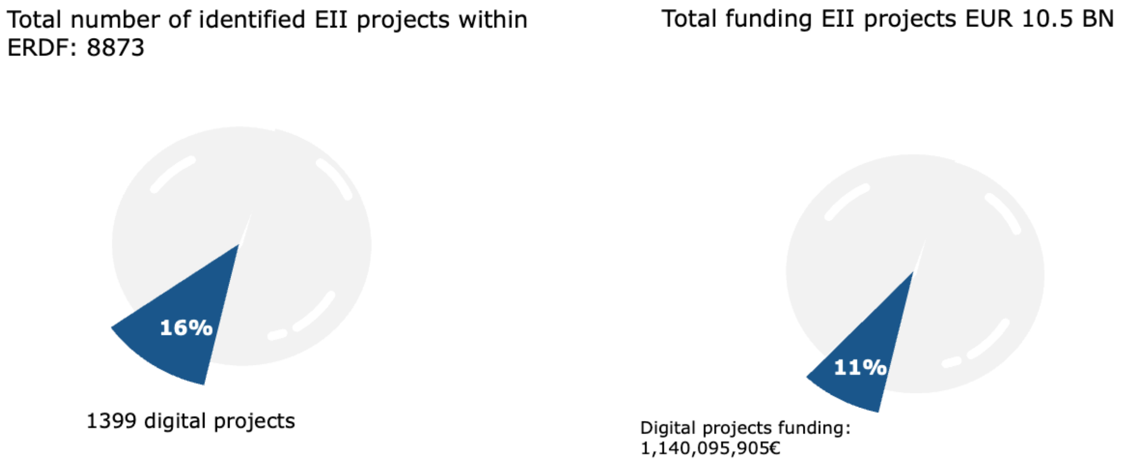
ERDF projects[121] that are related to the EII industrial ecosystem have been identified based on an analysis of the project descriptions[122]. The total number of **ERDF projects in the EII industrial ecosystem** that could be identified in 2014-2020 was 8 873, representing **a total funding of EUR 10.5 bn.**

The analysis shows that **about 11%** (or EUR 1.14 bn) **of the funding to EII ERDF projects supported the digital transition**. In terms of number of ERDF projects, **16%**

[118] The methodological report provides detailed insights into the methodology. In particular, the CORDIS data have been merged with the relevant EuroSciVoc data. EuroSciVoc connects projects to relevant scientific concepts, providing a deeper understanding of the research focus.
[119] Cut-off date is March 2024
[120] For this analysis, two data sources have been used and merged, namely the Cohesion Open Data maintained by the European Commission and the Kohesio data. For more information on the data sources and the approach, see the methodological report.
[121] The European Regional Development Fund (ERDF) supports projects aimed to strengthen economic, social and territorial cohesion in the European Union. It aims to correct imbalances between regions enabling investments in a smarter, greener, more connected and more social Europe that is closer to its citizens. The ERDF finances programmes in shared responsibility between the European Commission and national and regional authorities in Member States.
[122] Based on the codes of economic activity and additional keyword searches in the project descriptions.

is contributing to the digital transition (or 1 399 projects). Examples of ERDF projects supporting the digital transition in EII are presented in Box 4.

Figure 36: Total number of projects and funding going into EII and its digital transformation via ERDF



Source: Technopolis Group based on Kohesio data

Box 4. ERDF EII projects supporting the digital transition

Advanced manufacturing and robotics

"Commercialisation of photopolymeric materials for the manufacture of products with antistatic properties using stereolithographic 3D printing"

AI, Big Data and data analytics

"Advanced data analysis system for chemical product formulation in the cosmetics sector: the overall objective of the project focuses on the development and validation of knowledge and technologies in the domain of big data and machine learning, necessary to improve the process of chemical formulation products in the field of cosmetics. to do so, it carries out the construction of an advanced system for chemical product formulation that responds to the challenges of competitiveness associated with the transition to the current model of industry 4.0."

Internet of Things

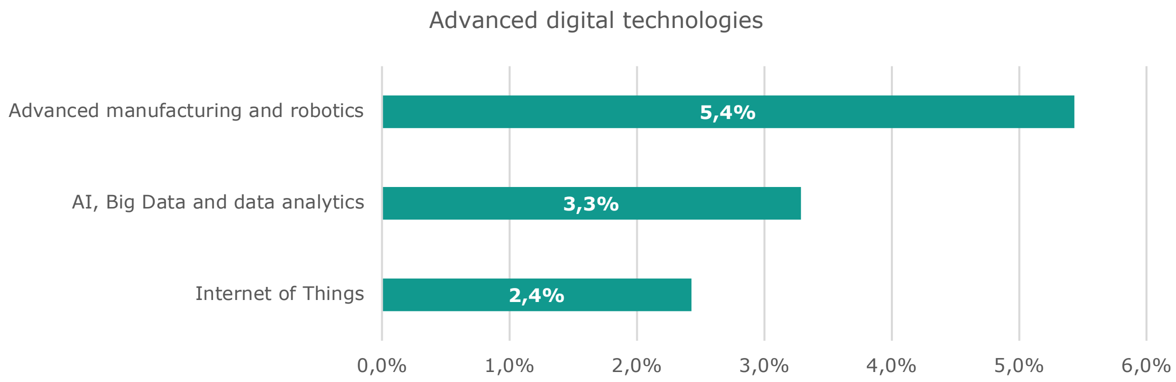
"Plasmatic: advanced predictive maintenance for the Valencian plastics industry: the objective of this project was to develop and validate knowledge and technologies needed for the incorporation of solutions for predictive maintenance in the plastics industry to meet the challenges of competitiveness, enrichment and sustainability of manufacturing industrial fabric."

Source: Technopolis Group based on Kohesio

When examining the ERDF projects that contribute to the digital transition in EII, 10% of the funding in these projects is going towards projects related to advanced digital technologies[123]. In particular, Figure 37 depicts that 5% of the EII projects contributing to the digital transition focused on advanced manufacturing and robotics.

[123] As identified for the purpose of this project, e.g., projects related to IoT, AI, Cloud, Blockchain, advanced manufacturing etc.

Figure 37: Share of funding contributing to the digital transition in the EII industrial ecosystem by category (2014-2020)



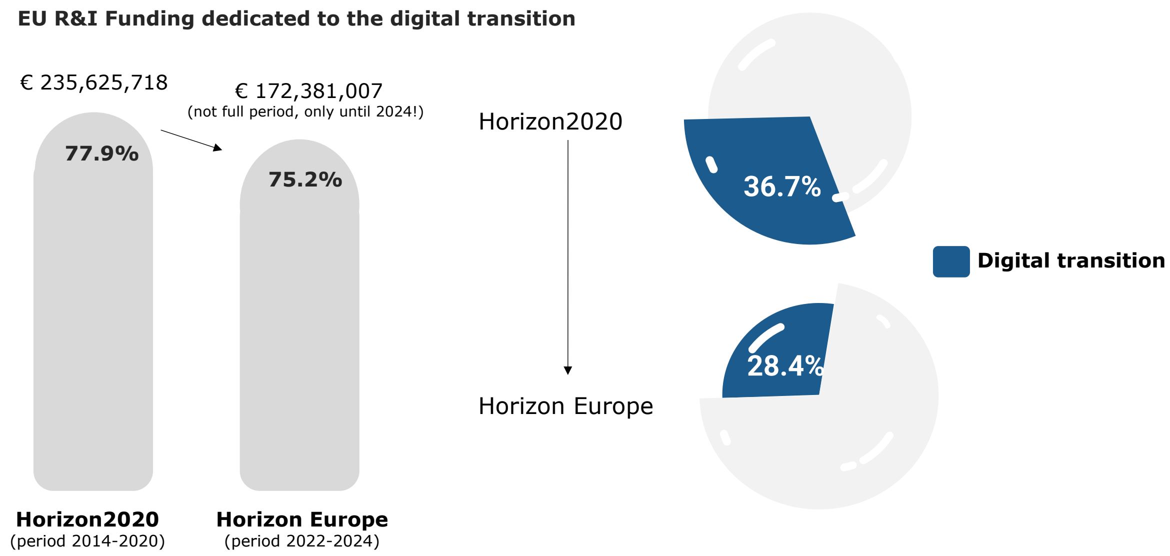
Source: Technopolis Group based on Kohesio

Framework Programmes

Funding data from the EC Framework Programmes for Research and Innovation, in particular from Horizon 2020 (2014-2020) and Horizon Europe (2021-2027) was analysed. The analysis of the CORDIS data demonstrates that the Horizon 2020 programme provided EUR 302.5 m to projects classified under the EII industrial ecosystem[124]. Horizon Europe thus far[125] provided EUR 229.2 million to EII projects.

In Horizon 2020, **36.7% of the EC funding to EII projects contributed to the digital transition**. In Horizon Europe, **28.4% of the EC funding** to date contributes to EII projects related to the digital transition.

Figure 38: Share of funding contributing to the digital transition in the EII industrial ecosystem via Horizon and Horizon Europe



Source: Technopolis Group based on CORDA

[124] The methodological report provides detailed insights into the methodology. In particular, the CORDIS data have been merged with the relevant EuroSciVoc data. EuroSciVoc connects projects to relevant scientific concepts, providing a deeper understanding of the research focus.
[125] Cut-off date is March 2024

3.2.2. Skills underpinning the digital transition

The Staff Working Document on the EII transition pathway identifies the **lack of digital skills among EII workers** as a key issue in the **EII industrial ecosystem** and identifies several actions to be undertaken by the European Commission and its Member States. These include support and investments into digital skills development, and collaborations with the industry and social partners to implement the skills partnerships under the Pact for Skills Social. The industry is requested to identify and anticipate skill requirements and training needs, develop roadmaps, curricula, and tools for upskilling/reskilling workers in the EII industrial ecosystem to use digital technologies, actively invest in digital skills, education and training.

A study[126] identified the most important skills needs for the EII in Flanders, Belgium. To facilitate the digital transition, technical knowledge and skills in digital set-up (e.g., robotic process automation techniques), use (e.g., use of predictive maintenance) and innovation (e.g., programming and data science) are required.

The **chemical subindustry** is facing exponential skills challenges as technologies such as AI and robotics are rapidly changing the workplace and the nature of the work and jobs. On top of that, the sector experiences notable skills gap, with a recent study indicating that there will not be sufficient science, technology, engineering, and math (STEM) graduates to fill skilled positions for chemical engineers, researchers, and scientists[127]. Also, as the workforce is ageing, this skills gap will grow.

To provide insights into the **skills demand and skills supply in the EII industrial ecosystem** related to the digital transition, this study builds upon two exploratory data sources, namely the Cedefop Skills-OVATE database and LinkedIn respectively[128].

Demand for digital skills

Skills demand in the EII industrial ecosystem has been analysed following the skills intelligence insights of Cedefop. These data provide insights into the job advertisements in the EII industrial ecosystem and on advanced and moderate digital skills that are in demand.

The total number of online job advertisements in the EII industrial ecosystem amounted to 139 863 in 2023 in the EU27. The results of the data analysis show that **12% of the job advertisements included a requirement of advanced digital skills** such as AI, big data, augmented and virtual reality, or cloud. **22% of the job advertisements required moderate digital skills** (referring to more than basic Microsoft or web skills, but not necessarily relying on artificial intelligence). The high growth in demand for specialised software skills between 2021 and 2023 also shows the importance of digitalisation beyond the more advanced digital skills such as AI or big data (see Figure below).

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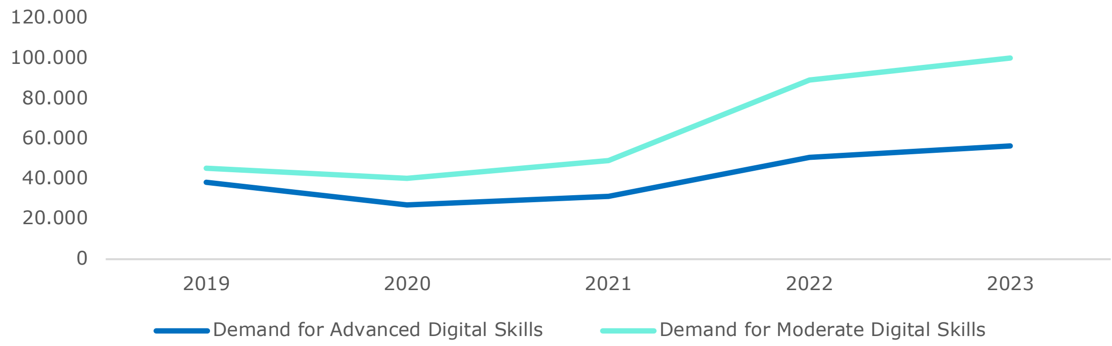
[126] Roland Berger (2021) A green Skills roadmap for the climate transition in the energy intensive industry. Retrieved from: https://klimaat.be/doc/just-transition-jobs-2023-flanders.pdf

[127] Deloitte (2022) The future of work in chemicals and materials. Retrieved from: https://www.deloitte.com/global/en/Industries/energy-chemicals/perspectives/gx-future-of-work-chemicals-and-materials.html

[128] More information on the data sources, the approach taken, and the limitations of the data, is found in the methodological report.

Figure 39: Number of online job advertisements with a requirement for digital skills in EII in the EU27



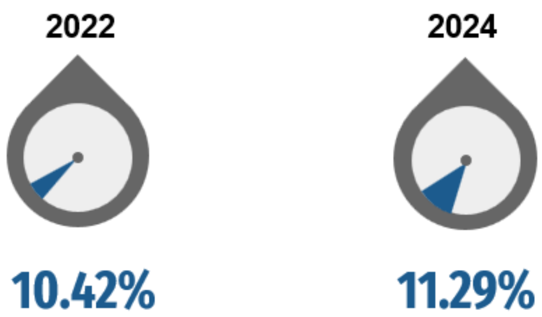
Source: Technopolis Group based on analysis of Cedefop data

Supply of digitally skilled professionals in the EII

The LinkedIn database has been consulted to gain insights into professionals working in the chemical subindustry, as one subindustry of the EII industrial ecosystem. Keywords have been defined to capture the advanced digital transition skills that professionals have. In particular, advanced digital skills have been again defined as artificial intelligence, cloud computing, big data, robotics, Internet of Things, augmented and virtual reality, digital security and blockchain, but advanced software technologies have been also included that are relevant for the industrial ecosystem .

There were 2.56 million professionals registered in chemical subindustry on LinkedIn in April 2024. Within these registered professionals, **11.29% indicated to have one type of digital skill in 2024**, which is an **increase** from 2022 where 10.42% were found to have at least one digital skill (see Figure 40).

Figure 40: Share of professionals in construction and plastics manufacturing professionals with advanced digital skills



Source: Technopolis Group based on LinkedIn

3.2.3. Demand for digital services by consumers

Chemical companies are increasingly implementing digitalisation to achieve business growth and meet societal and environmental expectations[129], with digital technology becoming an integral part of the value chain. In particular, the speed of digitalisation has

[129] Deloitte (2019) Achieving the next frontier of chemicals excellence. Digital maturity model to help ease the transition. Retrieved from: https://www2.deloitte.com/us/en/pages/energy-and-resources/articles/future-of-digitalization-in-the-chemical-industry.html

accelerated by 56% post pandemic, according to an EY survey[130]. With recent geopolitical disruptions and price fluctuations, consumers and the chemical subindustry require **resilient supply chains**. The EY survey indicates that almost 60% of respondents indicate that digitalisation has affected their supply chain planning in the past three years, which has triggered the use of digital tools for demand estimation and exploring consumption patterns, real-time tracking of orders, and tailoring of offerings to customer needs, for instance through the use of blockchain[131]. As a result, **chemical actors benefit from digitalisation through customer centricity**[132], enabling greater attention to customers' needs, improving customer experience, bringing greater transparency, convenience, flexibility, and providing new products and services faster and less expensive[133]. In addition, chemical actors have recognised that digitalisation can boost the **pursuit of sustainability**, which is increasingly valued and demanded by customers[134]. In the Transition Pathway for the Chemical Industry[135], the use of digital maturity assessment frameworks to support a successful digital transformation of the chemical subindustry, is encouraged. It also stresses the need for high-speed and reliable digital infrastructure to enable the power of digitalisation in the chemical subindustry, including the development of an open data platform data space for chemicals to ensure seamless access and combination of data and tools complying with GDPR, IP, confidential business information and access rights.

[130] EY. (2022) Why the chemical industry is prioritizing digitalization. Retrieved from: https://www.ey.com/en_uk/insights/advanced-manufacturing/why-the-chemical-industry-is-prioritizing-digitalization#:~:text=Digitalization%20is%20not%20only%20helping,achieving%20long%2Dterm%20sustainability%20goals.

[131] Arthur D. Little & CEFIC (2023) Digital Technologies for Sustainability in the European Chemical Industry. Retrieved from: https://cefic.org/app/uploads/2023/04/ADL_CEFIC_Digital_technologies_for_sustainability_2023.pdf

[132] EY (2022) Why the chemical industry is prioritizing digitalization.

[133] Arthur D. Little & CEFIC (2023) Digital Technologies for Sustainability in the European Chemical Industry.

[134] EY (2022) Why the chemical industry is prioritizing digitalization.

[135] European Commission (2023) Transition pathway for the chemical industry. Retrieved from: https://data.europa.eu/doi/10.2873/873037

3.3. Impact of digital technologies on industrial competitiveness

What is the progress of industrial efforts towards digitalisation?

- Digital transformation provides companies in the EII industrial ecosystem the opportunity **to improve operations by optimising logistics and processes with AI, sensors, and human-machine interfaces using AR/VR**.

- The EMI survey of EII companies reveals that the **adoption of advanced digital technologies has led to an increase in productivity of around 10%**. This increase in productivity can be attributed to the adoption of robotics and AI, according to respondents.

- Countries such as **Germany, France, Spain, Italy and Poland** that p**romote knowledge valorisation of digital and green technologies** through strong co-location patterns also showcase a strong performance in the EII industrial ecosystem in terms of production, trade and patents.

This section analyses the extent to which companies perceive digital technologies as enhancing their competitiveness, both for their business and the industry.

A central challenge that EII face in relation to their overall competitiveness is rooted in the energy transition and decarbonisation towards 2030 and beyond. EII companies experience a loss of competitiveness due to the energy price differential, limited access to affordable low carbon energy, increasing CO_2 costs and the overall investment intensity on the EU market[136]. The **digital transition has a key role to play in supporting the way in which EII can respond to these challenges and improve overall competitiveness**, highlighting the importance of the interplay of the twin transitions.

Digital transformation provides companies in the EII industrial ecosystem opportunities to improve operations by optimising logistics and processes with AI, sensors, and human-machine interfaces using AR/VR[137]. To give some illustrations, predictive maintenance minimises disruptions, while autonomous robots can improve safety and access to resources. Industrial data spaces enhance process and energy efficiency, and support circularity. Digital product passports offer transparency, allowing companies to differentiate based on environmental and social credentials. Cybersecurity is a crucial element of the digital transformation, with stringent measures needed to protect against cyber-attacks and IT failures. Legislative instruments and EU financial support through programs like the Single Market, Digital Europe, and Cohesion will facilitate digitalisation and improve overall competitiveness of EII companies.

The transition pathway for the **chemical subindustry**[138] highlights the importance digital technologies for the transformation of the sector, specifically: Internet of Things, big data, artificial intelligence, automation, smart sensors, digital twins and robotics, for product design, process design, production and logistics. In particular, it sets out two specific actions regarding the deployment of digital technologies:

- Deploy safe, high-speed, and reliable digital infrastructure

[136] ERT (2024) Competitiveness of European Energy-Intensive Industries. Retrieved from: https://ert.eu/wp-content/uploads/2024/04/ERT-Competitiveness-of-Europes-energy-intensive-industries_March-2024.pdf

[137] European Commission (2021) Commission Staff Working Document. For a resilient, innovative, sustainable and digital energy-intensive industries ecosystem: Scenarios for a transition pathway. Retrieved from: https://ec.europa.eu/docsroom/documents/47059

[138] European Commission (2023) Transition pathway for the chemical industry. Retrieved from: https://data.europa.eu/doi/10.2873/873037

- Deploy technologies to improve chemical manufacturing processes and data gathering

Many chemical companies have already deployed digital technologies or are planning to implement them in a variety of roles across the value chain[139]. 65% of chemical subindustry companies perceive the digitalization as an opportunity that will significantly impact their activities. An increasing area of importance is the digital security as well as the availability of technical infrastructure in order to ensure the robustness of digital solutions that are applied in support of industrial activities[140].

According to the EMI survey, artificial intelligence has had a considerable impact on the EII industrial ecosystem with 68% of EII businesses indicating they had adopted some form of AI technology in 2024 that increased the productivity of the company with an estimated 10%. According to 23% of the respondents, AI has the greatest impact on data analysis, as well as on automation of production processes (indicated by 15% of respondents). AI impacts job profiles in the companies that include especially marketing and sales, but also persons active in the area of finance, support staff and assistants. Although 64% of the companies surveyed said that they have not laid off any employees as a result of the use of AI systems, 35% said that they have employed less staff as a result of the adoption of AI technologies.

The survey of EII companies indicates that the adoption of advanced digital technologies increased productivity around 10%. The largest share of respondents witnessed an increase in productivity as a result of robotics followed by AI (see Table below). In the case of cloud computing, big data and in particular augmented and virtual reality, respondents also found that the investments did not yet pay off in terms of productivity gains.

Table 2 The impact on productivity of advanced digital technologies as expressed by the share of respondents in construction

	Increased	No change	Decreased
Robotics	92%	8%	
Artificial Intelligence	68%	32%	
Cloud computing	52%	46%	2%
Big Data	48%	44%	6%
AVR	50%	37%	13%
IoT	44%	56%	
Blockchain	45%	46%	9%

Source: EMI Enterprise Survey, 2024

[139] Arthur D. Little & CEFIC (2023) Digital Technologies for Sustainability in the European Chemical Industry. Retrieved from: https://cefic.org/app/uploads/2023/04/ADL_CEFIC_Digital_technologies_for_sustainability_2023.pdf

[140] EY (2022) Why the chemical industry is prioritizing digitalization. Retrieved from: https://www.ey.com/en_uk/insights/advanced-manufacturing/why-the-chemical-industry-is-prioritizing-digitalization#:~:text=Digitalization%20is%20not%20only%20helping,achieving%20long%2Dterm%20sustainability%20goals

The annual progress report of the chemical subindustry[141] indicates that the actions regarding the deployment of digital technologies are all in progress. The Digital Europe Programme currently supports the Common European Data Spaces, and reports that large businesses were the most active stakeholder in projects related to the deployment of digital technologies.

[141] European Commission (2024) 2023 annual progress report – Transition pathway for the chemical industry. Retrieved from: https://data.europa.eu/doi/10.2873/78547

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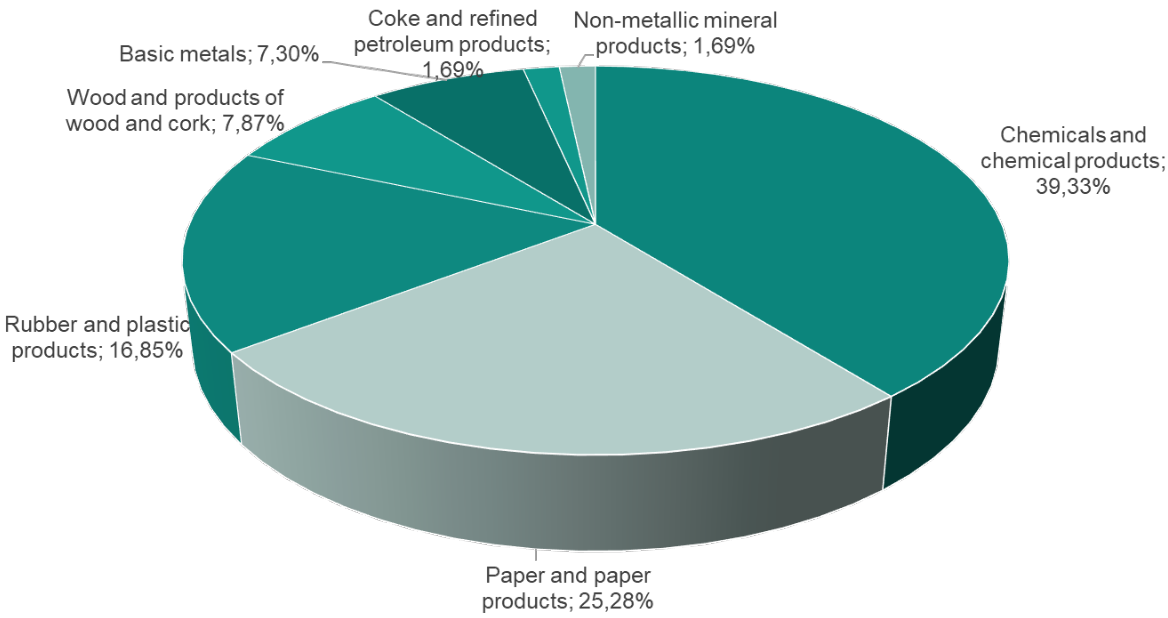
Appendix B: Methodological notes

EMI Survey 2024 – Sample of EII companies

The EMI Survey 2024 included a total of 672 companies. Sample distributions of companies according to the EII subindustry are depicted in Figure 41 below.

Figure 41: Survey sample distribution according to subindustry



Source: EMI Survey 2024

Crunchbase and Net Zero Insights

NACE		Crunchbase and Net Zero Insights
C20	Manufacture of chemicals and chemical products	Chemical, Chemical Engineering,

CORDIS

Keywords used: mining, steel and (industry OR production OR producin OR manufacture OR manufacturing), cement and (industry OR production OR producin OR manufacture OR manufacturing), fertiliser and (industry OR production OR producin OR manufacture OR manufacturing), iron and (industry OR production OR producin OR manufacture OR manufacturing), aluminium and (industry OR production OR producin OR manufacture OR manufacturing), plastic and (industry OR production OR producin OR manufacture OR manufacturing), paper and (industry OR production OR producin OR manufacture OR manufacturing), quarry, material extraction, mineral extraction, glass and (industry OR production OR producin OR manufacture OR manufacturing), refineries, wood and (industry OR production OR producin OR manufacture OR manufacturing), brubber and (industry OR production OR producin OR manufacture OR manufacturing), metal and (industry OR production OR producin OR manufacture OR manufacturing)

Exiobase

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

LinkedIn data analysis

Table 3: Concordance between NACE and LinkedIn

		NACE code
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	Paper and Forest Products
C17	Manufacture of paper and paper products	Paper and Forest Products
C19	Manufacture of coke and refined petroleum products	na
C20	Manufacture of chemicals and chemical products	Chemicals
C22	Manufacture of rubber and plastic products	Plastics
C23	Manufacture of other non-metallic mineral products	Glass, Ceramics and Concrete
C24	Manufacture of basic metals	Mining & Metals

Source: Technopolis Group based on LinkedIn

Green skills – keywords used: Cleantech, Sustainability, Sustainable Development, Sustainable Business, Energy Efficiency, Clean Energy Technologies, Renewable Energy, Wind Energy, Biomass, Biomass Conversion, Solar Energy, Solar Power, Urban Forestry, Forest Ecology, Sustainable Communities, Organic Farming, Organic Gardening, Urban Agriculture, Organic Food, Waste Management, Waste Reduction, Recycling, Water Treatment, Water Resource Management, Water Purification, Green Marketing, Green Printing, Environmental Biotechnology, Environmental Science, Environmental Engineering, Environmental Management Systems, Environmental Protection, Wastewater Treatment, Ecology, Circular Economy, Zero Waste, Waste to Energy, Plastics Recycling, E-Waste, Carbon Reduction Strategies, Carbon Footprinting, Carbon Neutral, Energy Retrofits, Biodiversity, Biodiversity Conservation, Nature Conservation, Advanced Materials, Nanomaterials, Biomaterials, Reuse, Separation Process, Sorting, Equipment Repair, Natural Resource Management, Sustainability Reporting, Green Development, Sustainable Cities, Energy Conservation, Energy Management, Environmental Awareness, Environmental Impact Assessment, Environmental Compliance, Leadership in Energy and Environmental Design (LEED), Environmental Policy, Green Technology, Sustainable Design, Sustainable Architecture, Environmental Consulting, Maintenance and Repair, Solar PV, Solar Cells, Wind Turbines, Wind Turbine Design, Carbon Capture, Low Carbon Technologies, Low Carbon, Renewable Fuels, Renewable Energy Systems, Renewable Resources, Integrated Water Resources Management, Natural Resources, Biodiesel, Bioplastics, Waste Treatment, Waste Water Treatment Plants, Electric Vehicles, Hybrid Electric Vehicles, Multi-modal Transportation, Energy Efficiency Consulting, Recycled Water, Adaptive Reuse, Ecodesign, Life Cycle Assessment, Energy Optimisation, Alternative Fuels, Green Building, Green Infrastructure, Green Purchasing, Biodegradable Products, ISO 14001, EMAS, Environmental Standards

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

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