European Commission

Monitoring the twin transition of industrial ecosystems

ENERGY INTENSIVE INDUSTRIES

Analytical report

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TABLE OF CONTENTS

TABLE OF FIGURES

Executive summary

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

The energy intensive industries represent the foundations of critical and strategic value chains that enable the EU economy and society, including transport, construction and power generation, as stated in the masterplan for a competitive transformation of EU energy intensive industries. The energy intensive industries (EII) ecosystem is important to Europe, as it employed almost 8 million people in 2019, realising a value-added of roughly €550 bn (or 5.9% of the EU total). The report takes a closer look at the steel industry and the chemical industry as the first forms the backbone for development, growth, and employment in Europe due to its close integration with Europe's manufacturing and construction industries, while chemicals are at the heart of Europe's major value chains, including pharmaceuticals, electronics, batteries for electric vehicles, and construction materials. The EU is the second-largest steel producer in the world, after China, while the chemical industry is the fourth largest manufacturing industry in Europe.

The energy intensive industries (EII) ecosystem is however subject to several challenges and have been negatively affected by the COVID-19 crisis due to, among others, substantial declines in demand in downstream industries. A main challenge of the ecosystem is the urgent need to reduce its carbon footprint, while, at the same time, stay competitive globally. While the EIIs have identified several technology pathways towards a low-carbon economy, these solutions typically entail high risks, require large capital investments, and often have high operating costs. Low-carbon technologies needed for the transition are often more expensive compared to fossil fuel-based production pathways, requiring substantial R&I investments to reach the European Green Deal emission targets. Regarding R&D&I investments, EU27 companies are focussing more on green technology investment in the energy intensive industries industrial ecosystem with over €48 bn in investments from 2017-2020.

In this project, the green and digital transition of industrial ecosystems have been analysed based on a tailored monitoring framework and dataset. The data include a business survey, text mining of company websites, startup data, patent applications, trade and production, investments, online job advertisements and job profiles and environmental impact data. The methodology of the data calculations is included in report on the conceptual and methodological framework.

Key findings about the green transition

Technological solutions are required for the energy intensive industries to transition towards a low-carbon economy. Important to the green transition in energy-intensive industries are recycling technologies that break down materials and transform them into valuable secondary raw materials to produce new products with the same quality as those made from fossil resources. Other critically important technologies relate to carbon capture, storage and utilisation or recycling. These refer to the processes to capture carbon dioxide from industrial processes, such as steel and cement manufacturing, for permanent sequestration (storage) or for use and recycling to produce other products of value.

An analysis of patent application related to the green and digital transition in EII reveals that **most patents are taken in the area of advanced sustainable materials**

(leading with 18.2%), followed by biofuels (9.7%) and recycling technologies (9.4%). The trends in patent applications related to the EII and green transition outweigh those related to the digital transition.

The skills required in the energy intensive industries ecosystem are rapidly evolving, hence a Skills Partnership for Energy Intensive Industries has been established. In the MoU of the Skills Partnership, the lack of skills and education is recognised as an important bottleneck to realise the full potential of new technological solutions within and across companies. Based on an analysis of LinkedIn data, **6.2% of the professionals employed in energy intensive industries have skills relevant for the green transition**. Among the supply of professionals with specific green skills within the EII ecosystem, the more sought after advanced green skills are: application of transport industry management concepts in order to improve transportation processes, reduce waste, increase efficiency, and improve schedule preparation; science of biology; and energy efficiency.

The EII ecosystem is performing better than average compared to the other ecosystems in terms of investments related to the green transition according to the Annual Single Market Report 2022. Particularly, close to 50% of the EU firms in the ecosystem have already invested in efforts to mitigate the impact of physical and transition risks and reduce carbon emissions. In the chemical industry specifically, the integrated production of hydrogen with low carbon footprint is leading R&D&I investments based on an ongoing study using ORBIS, Dealroom, patent and Technote data, with €19.6 bn of investments, followed by electrification (€11.4 bn) and non-conventional energy sources in process industry including carbon capture and use (€11.1 bn).

Analysing the results of a business survey and text mining of company websites, reveals that **60.4% of SMEs respondents have increased their investments dedicated to the green transition and environmental sustainability during the past five years**, while 46.4% of the respondents invested between 5-9% of their revenue in green transformation on average annually. The results also reveal that SMEs in the EII ecosystem adopted most easily the use of recycled materials and recycling technologies with a share of 20.4% and 20.2% respectively. While energy-saving technologies are only the third solution adopted by SMEs, 60.5% of respondents cover between 20-50% of their total consumption with renewable energy.

Industry startups in the chemical industry, leading the green transition, are active in the field of recycling technologies (43.6%), advanced materials (22.9%) and low carbon technologies (7.2%). The focal areas include recycling technologies, water recovery and recycling, and catalyst recycling, as catalysts are fundamental to many chemical reactions. **In the steel industry, startups are active in recycling technologies (24.1%), advanced materials (6.1%), energy saving technologies (4.8%) and renewable energy technologies (4.4%).**

Key findings about the digital transition

Digitalisation is driving the energy-intensive industries with the aim of increasing production efficiency, safety, sustainability, and facilitating the green transition through optimised logistics, predictive maintenance, and autonomous robots. At the same time, with regard to investments related to the digital transition, the EII ecosystem is in the middle to lower end compared to the other industrial ecosystems. To address the challenges related to the digital transformation of the EII ecosystem, the Transition Pathway for the Chemical Industry entails a set of actions to support the development and deployment of new and available technologies for the digitalisation of the chemical value chain.

Based on an analysis of LinkedIn data, **18% of the professionals working in the EII ecosystem claimed having at least one type of moderate digital skills and 4% having digital skills in areas such as Internet of Things, cloud, AI, big data, cybersecurity, robotics, blockchain, augmented and virtual reality.** Among the supply of professionals with specific digital skills within the EII ecosystem, the more sought after advanced digital skills are technical drawings and classification of databases (their purpose, characteristics, terminology, models and use such as XML databases, document-oriented databases and full text databases, next to monitoring and operating computer numerical controlled machines.

Start-ups play a key role in the digital transition of the EII ecosystem. **In the steel industry, a total of €124 m has been invested in startups, with a sharp increase since 2018**. As regards digital technologies, companies developing advanced manufacturing techniques and micro- and nanoelectronics and photonics have been the most successful among investors, however collectively not gathering as much interest as the green transition technologies. Investment directed towards companies developing advanced manufacturing reached a total of €78 m for the considered period (2010-2022). Most of this funding was raised by companies focused on 3D printing, indicating a consistent interest of investors in these technologies. **Advanced manufacturing and robotics are also the main digital technology for the EII industrial ecosystem in terms of patenting (25.7%).**

Zooming in on tech startups in the chemical industry, advanced manufacturing makes up the greatest share of 8.3%, followed by 5.4% with micro- and nanoelectronics and photonics and Internet of Things (4.0%). Startups active in the area of advanced manufacturing are active in the area of 3D printing and IoT. Looking at startups active in the steel industry, again most startups are active in advanced manufacturing (21.9%), followed by robotics and automation (13.6%) with some activities related to cloud-based and other software solutions, and artificial intelligence.

Results of a **large-scale business survey highlight that 36.61% of the survey respondents indicated that they had increased their investments dedicated to digital technologies over the past five years, with 40% of respondents investing less than 5% of their revenue in digital technologies.** The digital technologies that are most adopted by respondent SMEs are cloud technologies (29.1%) and online platforms (27.4%).

1. Introduction

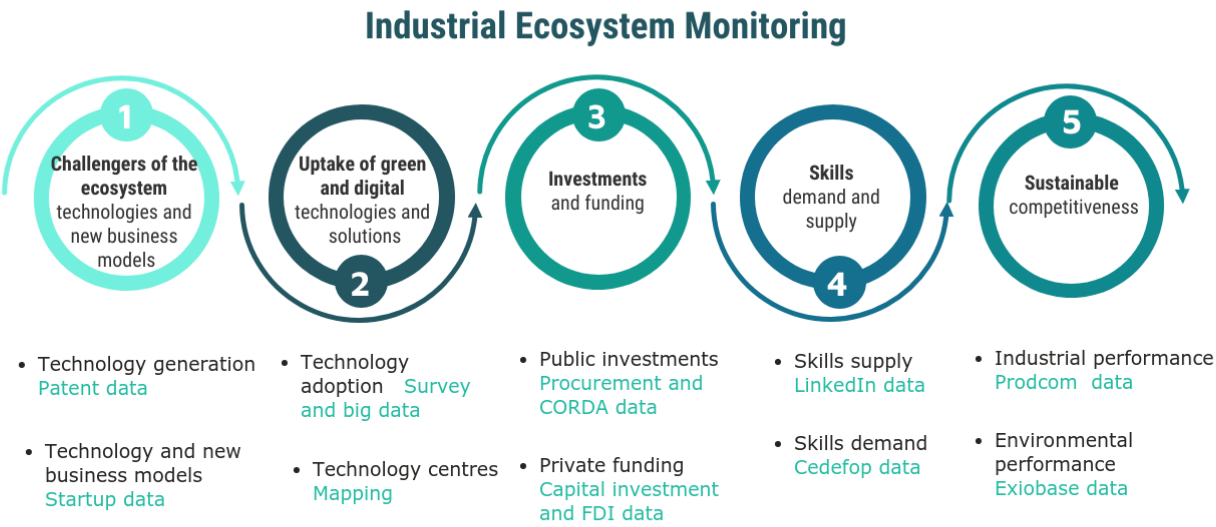
1.1 Objectives

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

The EU's updated industrial strategy[1] has identified 14 industrial ecosystems[2] – one of them being '**Energy-Intensive Industries'** - 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.

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

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



Source: Technopolis Group, IDEA Consult and Fraunhofer ISI

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

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

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

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

Figure 2: Main technologies monitored in the project

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

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

Source: Technopolis Group, IDEA Consult and Fraunhofer ISI

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

1.2 Definition of the ecosystem

This section highlights the definitions used to **delineate the energy intensive industries industrial ecosystem** (see Figure 3).

The energy intensive industries comprise a whole range of different industries. In terms of the statistical classification of economic activities in the European Community (NACE), the ecosystem definition includes:

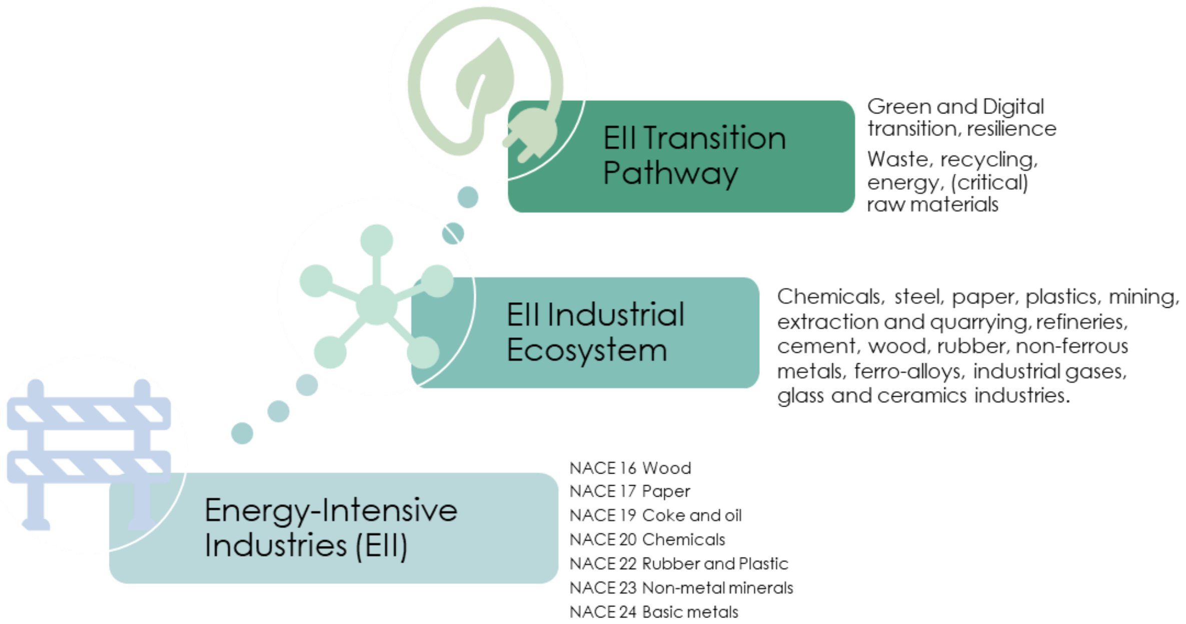
- C16 Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
- C17 Manufacture of paper and paper products
- C19 Manufacture of coke and refined petroleum products

[3] https://ec.europa.eu/docsroom/documents/49407/attachments/1/translations/en/renditions/native

- 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

For the purpose of this study, we focus on the energy intensive industries industrial ecosystem as it is outlined in the Industrial Strategy[4] and Annual Single Market Reports.

Figure 3: Positioning of the energy intensive industries industrial ecosystem definitions



Source: IDEA Consult based on the definition of the energy intensive industries ecosystem as described in the Annual Single Market Report (2021) and the Scenarios for a Transition Pathway (2021)

According to the European Commission's Annual Single Market Report 2021, the Energy Intensive Industries (EII) industrial ecosystem "covers chemicals, steel, paper, plastics, mining, extraction and quarrying, refineries, cement, wood, rubber, non-ferrous metals, glass, and ceramics." In addition, the EII is closely interlinked to several downstream sectors as well as energy providers and waste and recycling industries due to their reliance on secondary raw materials.[5]

Practically following this definition, this report will, in data collection and analysis, focus on activities in the indicated sectors. For the energy intensive industries ecosystem, the

[4] European Commission European Industrial Strategy https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-industrial-strategy_en
[5] European Commission (2021) Annual Single Market Report 2021 https://commission.europa.eu/system/files/2021-05/swd-annual-single-market-report-2021_en.pdf

Scenarios for a transition pathway has been published in 2021[6] together with the Transition Pathway for the Chemical Industry in 2023.[7] [8] [9]

1.3 Industry state of play

The energy intensive industries (EII) ecosystem is important to Europe, not in the least because it supplies basic materials employed across the whole economy. In 2019, almost 8 million people were employed in the industrial ecosystem and the value-added was roughly €550 bn (or 5.9% of the EU total)[10]. In total, there were 547,745 firms in the ecosystem in 2018[11] and SMEs represent about 99% of these companies[12]. In terms of company size, only 11.9% of the workers in the ecosystem are employed in companies with 0-9 persons, with 50.9% employed by an SME. 49.1% of the workers are employed in large companies and these companies account for 62.7% of the value added of the ecosystem.[13] The sector "chemicals and chemical products" (NACE C20) has the highest gross value added in the ecosystem in 2018. The sector "rubber & plastic products" (NACE C22) is the largest sector in terms of employment.[14]

Two important industries in the energy intensive industries are the steel industry and the chemical industry. Closely integrated with Europe's manufacturing and construction industries, the **steel industry** is a backbone for development, growth, and employment in Europe. The EU is the second-largest steel producer in the world, after China. Recent data show that at the end of 2021, the steel industry had a turnover of around €125 bn and directly employed almost 310,000 people, producing on average 153 million tonnes of steel per year.[15] Additionally, steel is 100% recyclable, hence a fundamental element of the circular economy and essential in the development and deployment of CO_2-mitigating technologies. [16] Also the **chemical industry** is critically important to the EU. This is reflected by the 1.2 million direct jobs it provided in 2021 and the €594 bn of sales it generated in the EU27 in 2021. Moreover, the chemical industry is the fourth largest manufacturing industry in Europe[17] [18]. In terms of total sales, the EU chemical industry is the second-largest producer in the world, after China.[19] There is, however, an uneven distribution of the sector in the EU Member States (MS). In 2021, roughly two thirds of the EU27 chemical sales were generated in four MS, namely Germany, France, Italy and the Netherlands.[20]

The total production value for the Energy Intensive Industries industrial ecosystem gives insight into the production performance of the overall ecosystem as delineated by the NACE

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[6] European Commission (2021) For a resilient, innovative, sustainable and digital energy-intensive industries ecosystem: Scenarios for a transition pathway. SWD(2021) 277 final

[7] European Commission (2023) Transition Pathway for the Chemical Industry https://ec.europa.eu/docsroom/documents/53754

[8] Transition pathways for European industrial ecosystems. https://single-market-economy.ec.europa.eu/industry/transition-pathways_en

[9] European Commission (2023) Annual Single Market Report 2023. https://single-market-economy.ec.europa.eu/system/files/2023-01/ASMR%202023.pdf

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

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

[12] SWD(2021) 277 final. For a resilient, innovative, sustainable and digital energy-intensive industries ecosystem: Scenarios for a transition pathway.

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

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

[15] Eurofer. (2022). European Steel in Figures 2022. https://www.eurofer.eu/assets/publications/brochures-booklets-and-factsheets/european-steel-in-figures-2022/European-Steel-in-Figures-2022-v2.pdf

[16] Ibid

[17] https://transition-pathway.cefic.org/

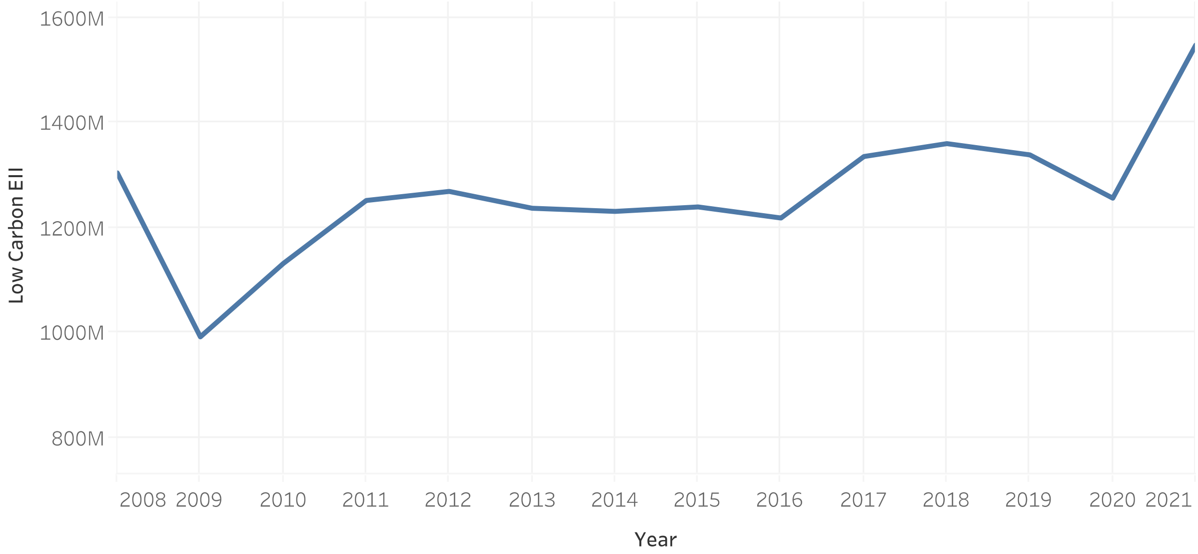
[18] European commission (2023). Transition Pathway for the Chemical Industry.

[19] https://cefic.org/app/uploads/2023/03/2023-Facts-and-Figures.pdf

[20] CEFIC (2023) The European Chemical industry Facts and Figures 2023 https://cefic.org/app/uploads/2023/03/2023-Facts-and-Figures.pdf Accessed on 8 November 2023

2 classification and weights identified in the Annual Single Market Report.[21] Data on production from Eurostat, notably Prodcom statistics, reveal the total values of production of manufactured goods carried out by enterprises located in EU27 over 14 years (from 2008 until 2021).[22] Results depicted in Figure 4 present the weighted sum of production of manufactured goods aggregated at NACE 2-digit level for the EII industrial ecosystem (thousands of euros).

Figure 4: Production performance of Energy Intensive Industries industrial ecosystem in EUR thousands for 2008-2021



Source: IDEA Consult based on Eurostat [prom]

Aside from economic crises and the clear evident impact of the COVID-19 pandemic, **the production value of the EII industrial ecosystem shows continuous growth for the indicated time frame.** This highlights the overall importance of EII related production.

The energy intensive industries have been negatively affected by the **COVID-19 crisis**. According to the Annual Single Market Report (2021), the annual production dropped significantly in 2020, with drops ranging from around 22% in the steel sector, 10-16% in cement, 10-15% in flat glass, and 1-11% in non-ferrous metals.[23] These drops are largely driven by substantial declines in demand in downstream industries, especially in the automotive and construction industry, as well as by border closures.[24] In 2021, a **strong but uneven recovery was noticeable**, 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, leading to decreased production in downstream sectors, such as automotive, and hence in demand for several EII products).[25]

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[21] European Commission (2021) Annual Single Market Report 2021.
[22] Eurostat Prodcom https://ec.europa.eu/eurostat/web/prodcom/data/database
[23] European Commission (2021) Annual Single Market Report 2021 https://commission.europa.eu/system/files/2021-05/swd-annual-single-market-report-2021_en.pdf
[24] SWD(2021) 277 final. For a resilient, innovative, sustainable and digital energy-intensive industries ecosystem: Scenarios for a transition pathway. https://ec.europa.eu/docsroom/documents/47059/attachments/1/translations/en/renditions/native
[25] SWD(2021) 277 final. For a resilient, innovative, sustainable and digital energy-intensive industries ecosystem: Scenarios for a transition pathway. https://ec.europa.eu/docsroom/documents/47059/attachments/1/translations/en/renditions/native

Although the **steel industry** suffered consequences of Brexit and the COVID-19 pandemic, in general, the industry showed a strong rebound in the beginning of 2021. Nevertheless, demand for steel started to slow down again in the second half of that year.[26] The impact of COVID-19 on the **chemical sector** was largely dependent on the market in which the companies are active. Particularly, production and supply of chemicals that are necessary in critical supply chains (e.g., medical and food sectors) have been prioritized and secured as much as possible in the aftermath of the COVID-19 pandemic. Chemical companies providing input to sectors such as textiles suffered more from the negative impacts of COVID-19.[27]

Challenges for the industry

The energy intensive industries ecosystem is characterised by a high energy and carbon intensity, and as such is faced with multiple, interrelated challenges. A main challenge of the ecosystem is the urgent need to **reduce its carbon footprint**, while, at the same time, stay **competitive** globally. This is particularly important as the energy intensive industries consume about 83% of the final energy used by EU industries (2018)[28] and represent the foundations of other value chains such as transport, construction, and power generation.[29] As such, the EII ecosystem is subject to many EU, national, and regional environmental regulations and policy measures, among others including the Emissions Trading System (ETS).[30]

While the EIIs have identified several technology pathways towards a low-carbon economy, these solutions (e.g., hydrogen technologies and carbon capture, utilisation and storage) typically entail high risks, require large capital investments, and often have high operating costs.[31] EIIs hence require **significant investments** in R&D, infrastructure, upskilling and reskilling of the workforce and the roll-out of low-carbon technologies.[32] Yet, it is argued that there is a gap between the current overall research and innovation investments across energy intensive industries and the amount needed to reach the European Green Deal objectives.[33] The high costs, low immediate returns, long investment cycles, and uncertainty about the global economic recovery affect the necessary investment decisions.

Another challenge is the international nature of the industry. Particularly, steel, non-ferrous metals, chemicals and many other EIIs operate in global markets where products are traded globally at **international prices** with very limited possibility for passing additional costs related to higher regulatory requirements to downstream customers. In this international context, Russia's invasion of Ukraine is also a reminder that the EU has to

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[26] SWD(2021) 277 final. For a resilient, innovative, sustainable and digital energy-intensive industries ecosystem: Scenarios for a transition pathway. https://ec.europa.eu/docsroom/documents/47059/attachments/1/translations/en/renditions/native

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

[28] Eurostat

[29] European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Masterplan for a competitive transformation of EU energy-intensive industries enabling a climate-neutral, circular economy by 2050 – , Publications Office, 2019, https://data.europa.eu/doi/10.2873/854920

[30] European Commission (2023) EU Emission Trading System (ETS) https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en

[31] European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Masterplan for a competitive transformation of EU energy-intensive industries enabling a climate-neutral, circular economy by 2050 – , Publications Office, 2019, https://data.europa.eu/doi/10.2873/854920

[32] European Parliament, Directorate-General for Internal Policies of the Union, Bruyn, S., Jongsma, C., Kampman, B.et al., Energy-intensive industries – Challenges and opportunities in energy transition : in-depth analysis, European Parliament, 2020, https://data.europa.eu/doi/10.2861/427814

[33] European Commission, Directorate-General for Research and Innovation, ERA industrial technology roadmap for low-carbon technologies in energy-intensive industries – , Publications Office of the European Union, 2022, https://data.europa.eu/doi/10.2777/92567

drastically increase its **energy independence** from Russia, for instance by accelerating the clean energy transition.

The **working group on steel of the Just Transition Platform**[34] identified several challenges particularly for this sector. It indicates that carbon-neutral primary steel production is a true challenge as process emissions inevitably occur during many production steps. Also, it is not optimal to integrate new technologies in the existing structures and plants, yet investing in entirely new infrastructure is extremely costly. Furthermore, steel will need to be reused while at the same time reducing the consumption of materials and energy to create steel to stimulate circularity. A shift in technologies and production processes require new skills as well as public acceptance. A first challenge, identified by the working group, is related to replacing carbon intensive energy sources. Specifically, the shift from fossil fuels towards carbon-free energy sources is a major challenge as dependence on fossil fuels is still very high. Second, investments to change or modernise infrastructure are critically important to be able to develop new technologies. Finally, investments in re- and upskilling and new jobs are deeply needed to avoid heavy job losses and make chemical workers ready for employment in other sectors.[35]

[34] https://ec.europa.eu/regional_policy/funding/just-transition-fund/just-transition-platform/about_en

[35] Just Transition Platform: Working Group on Chemicals Scoping Paper May 2022

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

Key findings

Technological solutions are required for the energy intensive industries to transition towards a low-carbon economy, including low-carbon technologies, such as electrification (i.e., the use of electricity in applications including electrode boilers, heat pumps and steam recompression) and the use of hydrogen and biomass.

Important to the green transition in energy intensive industries are recycling technologies that break down materials and transform them into valuable secondary raw materials to produce new products with the same quality as those made from fossil resources. The chemical industry for example has developed solutions to recycle mixed and contaminated plastic waste through different routes (e.g., dissolution, depolymerisation or conversion).

Digitalisation is driving the energy intensive industries with the aim of increasing production efficiency, safety, sustainability, and facilitating the green transition through optimised logistics, predictive maintenance, and autonomous robots. In general, patent applications in the EII vary by world region, with a slight decreasing trend in the EU27, compared to a slight increase in the USA versus a strong decrease in Japan and a strong increase in China over the period of 2010 to 2020. An analysis of patenting activities related to the green and digital transition reveals that the trends in patent applications related to the EII and green transition outweigh those related to the digital transition. Within the green transition technologies, **advanced sustainable materials** are leading with 18.2%, followed by **biofuels** (9.7%) and **recycling technologies** (9.4%). Related to the digital transition, **advanced manufacturing and robotics** is the main digital technology for the EII industrial ecosystem in terms of patenting (25.7%).

Data from the Crunchbase and Net Zero Insights database has been sourced to analyse technology startups and companies active in the chemical and steel industrial ecosystem. For the chemicals industry, the green transition is clearly leading the way in terms of number of companies founded over the period of 2010 to 2022. The digital transition is clearly present with a slowly increasing trend, while those tech startups active in both the green and digital transition also make up an increasing portion, highlighting the importance of the twin transition. Within the chemicals industry startups, the technologies leading the green transition are **recycling technologies (43.6%), advanced materials (22.9%) and low carbon technologies** (7.2%). Among the digital transition technologies, advanced manufacturing makes up the greatest share at 8.3%, followed by 5.4% with micro- and nanoelectronics and photonics and Internet of Things (4.0%). For the steel industry, from 2017 onwards, the green transition took clear and continuing precedence over the digital transition, underpinning the need for greening of the overall industry.

The share of technologies used by steel tech startups founded in the period of 2010 to 2022 are dominated by recycling technologies (24.1%), followed by activities in other areas of the green transition namely advanced materials (6.1%), energy saving technologies (4.8%) and renewable energy technologies (4.4%). In the area of digital technologies, the main technologies include advanced manufacturing (21.9%) and robotics and automation (13.6%) with some activities related to cloud-based and other software solutions, and artificial intelligence, among others.

For the EIIs to become climate neutral while remaining competitive on a global market, **technological solutions** are required for the transition towards a low-carbon economy.[36] Those technologies are currently at different technology readiness levels (TRL) and will be crucial to reaching the 2030 and 2050 emission targets and reducing the industry's dependence on gas.[37] Recent reports list important low-carbon technologies, such as **electrification** (i.e., the use of electricity in applications including electrode boilers, heat pumps and steam recompression) and the use of **hydrogen** and **biomass**.[38] These technologies disincentivise the use of fossil fuels, cut emissions, and count on the availability of green, renewable electricity as an energy source.[39]

Also important to the green transition in energy intensive industries are **recycling technologies**[40] that break down materials and transform them into valuable secondary raw materials to produce new products with the same quality as those made from fossil resources. For instance, by means of **chemical recycling technologies**, the chemical industry has developed solutions to recycle mixed and contaminated plastic waste[41] through different routes (e.g., dissolution, depolymerisation or conversion).[42] Increasing the plastic recycling rate is critically important as, in Europe, roughly 30 million tonnes of plastic waste are collected yearly, of which 84% are still incinerated, exported, or sent to landfill.[43]

Other critically important technologies relate to **carbon capture, storage and utilisation or recycling**. These refer to the processes to capture carbon dioxide from industrial processes, such as steel and cement manufacturing, for permanent sequestration (storage) or for use and recycling to produce other products of value.

Furthermore, **digitalisation** is driving the energy intensive industries with the aim of increasing production efficiency, safety, sustainability, and facilitating the green transition. The EII transition pathway describes several ways in which EII companies can improve their operations thanks to digital transformation. For instance:

- logistics and process operations can be optimised by connecting sensors and controls in real time with artificial intelligence (AI);
- predictive maintenance can reduce the frequency of disruptions and the length of downtimes; and
- autonomous robots can provide access to remote raw material deposits and improve occupational health and safety.

[36] IPOL Energy-intensive industries- Challenges and opportunities in energy transition
[37] European Commission, Directorate-General for Research and Innovation, ERA industrial technology roadmap for low-carbon technologies in energy-intensive industries – , Publications Office of the European Union, 2022, https://data.europa.eu/doi/10.2777/92567
[38] European Parliament, Directorate-General for Internal Policies of the Union, Bruyn, S., Jongsma, C., Kampman, B.et al., Energy-intensive industries – Challenges and opportunities in energy transition : in-depth analysis, European Parliament, 2020, https://data.europa.eu/doi/10.2861/427814; European Commission, Directorate-General for Research and Innovation, ERA industrial technology roadmap for low-carbon technologies in energy-intensive industries – , Publications Office of the European Union, 2022, https://data.europa.eu/doi/10.2777/92567
[39] European Commission, Directorate-General for Research and Innovation, ERA industrial technology roadmap for low-carbon technologies in energy-intensive industries – , Publications Office of the European Union, 2022, https://data.europa.eu/doi/10.2777/92567
[40] European Parliament, Directorate-General for Internal Policies of the Union, Bruyn, S., Jongsma, C., Kampman, B.et al., Energy-intensive industries – Challenges and opportunities in energy transition : in-depth analysis, European Parliament, 2020, https://data.europa.eu/doi/10.2861/427814
[41] Cefic. (2022). Position paper. Chemical recycling: Enabling plastic waste to become a valuable resource. https://cefic.org/app/uploads/2022/04/Cefic-position-paper-on-Chemical-Recycling.pdf
[42] https://cefic.org/a-solution-provider-for-sustainability/chemical-recycling-making-plastics-circular/
[43] https://cefic.org/a-solution-provider-for-sustainability/chemical-recycling-making-plastics-circular/

Additionally, digitalisation has the power to change business models, for instance through **digital product passports**, which provide consumers detailed information about environmental characteristics of products and allow companies to differentiate themselves from competitors based on the shares of recycled materials and the overall environmental footprint.[44]

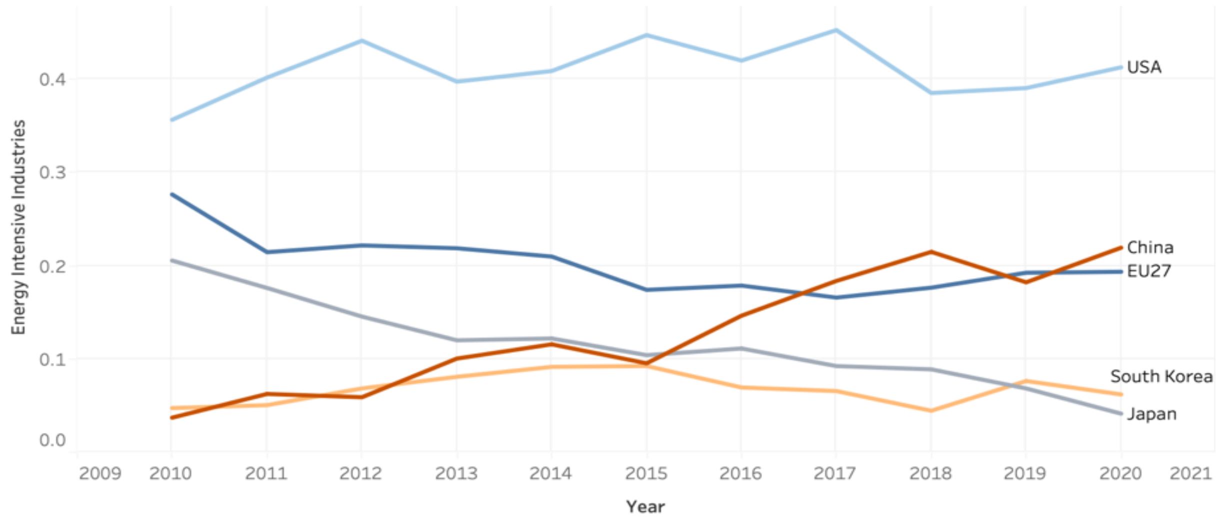
In the **chemical sector**, many digital technologies are already established, including advanced data generation, processing and analysis, AI and supercomputing for predictive maintenance, and development of digital twins. These technologies however, need to be further scaled up and mainstreamed.[45] According to chemical players, the biggest barriers to digitalisation are the lack of technical infrastructure, security concerns, and very high investment requirements.[46]

2.1 Technological trends

Technology developments have been tracked by patenting activities related to the specific sectoral activities based on patent-based classifications. 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 based 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 energy intensive industries industrial ecosystem, are defined based on search that refer to patent classifications (IPC) and/or use keywords to identify relevant applications across classes. The detailed methodology is presented in the EMI methodological report.

Figure 5 presents the trends in the evolution of patent applications related to the EII industrial ecosystem as a share in the world total patent applications.

Figure 5: Trends in the EU27 share of patent applications in world total in the field of the EII industrial ecosystem in 2010-2020 and global comparison in 2020



Source: Fraunhofer calculations, Patstat

[44] SWD(2021) 277 final. For a resilient, innovative, sustainable and digital energy-intensive industries ecosystem: Scenarios for a transition pathway. https://ec.europa.eu/docsroom/documents/47059/attachments/1/translations/en/renditions/native

[45] http://www.suschem.org/highlights/the-digital-chemical-industry-what-is-next referred to by Cefic (https://cefic.org/media-corner/newsroom/digitalisation-a-win-win-for-environment-and-quality-of-life/)

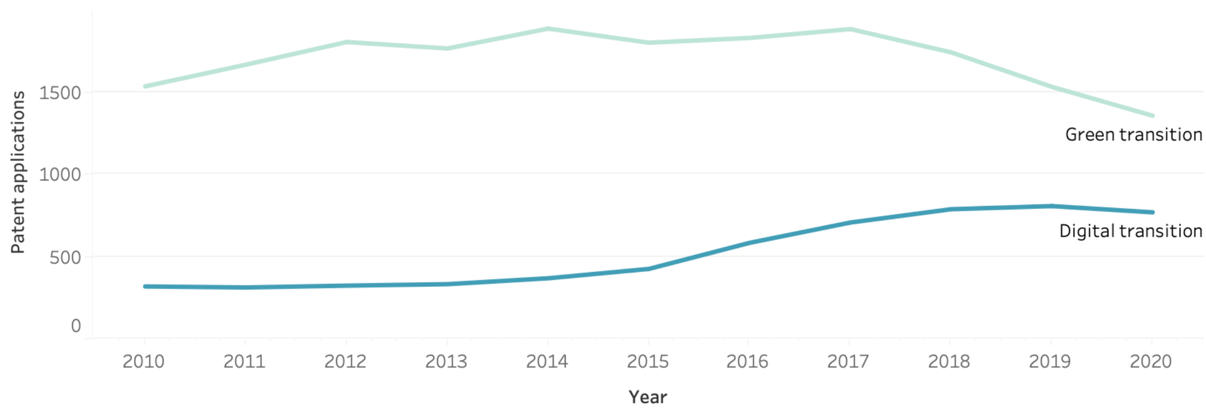
[46] https://www.ey.com/en_gl/advanced-manufacturing/why-the-chemical-industry-is-prioritizing-digitalization#:~:text=Chemical%20and%20other%20manufacturing%20players,for%20production%20and%20emission%20control.

In general, patents application trends vary depending on world region, with a slight decreasing trend in the EU27, compared to a slight increase in the USA versus a strong decrease in Japan and a strong increase in China over the period of 2010 to 2020.

A further analysis was conducted with a particular focus on digital and green transition. In this process, the analysis of digital and green patent applications related to the ecosystem that was based on the 2022 PATSTAT database as well, but exclusively focused on WIPO applications. Both the industrial ecosystem and specific technologies were delineated by a set of Cooperative Patent Classification (CPC) categories. A text mining algorithm was used to search for key words and their specific association in the text of patent documents as well as in the Cooperative Patent Classification nomenclature. By using this approach, it is possible to capture representatively the patenting activity in the entire ecosystem and observe trends in the distribution and development with a view to specific technologies. The classification of green transition technologies builds upon the OECD green patents classification that was augmented by including additional technologies particularly relevant to the ecosystems.

As a result, Figure 6 shows the number of green and digital patent applications from 2010 to 2020. Overall, the trends in patent applications related to the EII and green transition outweigh those related to the digital transition. However, the green transition specific patents are decreasing over the period from 2017 to 2020, whereas the digital transition patents are rising from 2015 onwards, highlighting the interplay between these two transitions.

Figure 6: Trends over time in digital and green transition related patent applications connected to EII industrial ecosystem



Source: Balland, 2022 based on PATSTAT

Zooming in on the specific technologies related to the green and digital transition, Figure 7 shows the distribution of patents by digital and green transition related technologies applied in the EII industrial ecosystem. Within the green transition technologies, **advanced sustainable materials** are leading with 18.2%, followed by **biofuels** (9.7%) and **recycling technologies** (9.4%). It is evident that the EU and USA are leading in terms of green transition patenting compared to China. Related to the digital transition, **advanced manufacturing and robotics** is the main digital technology for the EII industrial ecosystem in terms of patenting, making up 25.7%. While the EU and USA are on level playing field, China is lagging in terms of their share of patenting in this technology area.

Figure 7: International comparison in digital and green technology related patenting in EII – share of the EU27, USA, China patent applications in EII within total EU-China-USA patent applications in the respective technologies and EII ecosystem (over the period 2017-2021)

Technologies	EU27 share of tech in the industry within EU total industry	USA	China
Green transition			
Advanced sustainable materials	18,2%		
Biofuels	9,7%		
Recycling technologies	9,4%		
Waste management	8,5%		
Air & water pollution reduction	7,3%		
Batteries	4,5%		
Hydrogen	2,9%		
Wind energy	2,1%		
Greenhouse gas capture	1,9%		
Solar energy	1,8%		
Water related adaptation technologies	0,6%		
Other energy storage	0,3%		
Digital transition			
Advanced manufacturing and robotics	25,7%		
Cybersecurity	0,8%		
Quantum computers	0,4%		
Augmented and virtual reality	0,3%		
Artificial intelligence	0,1%		
Blockchain	0,1%		
Internet of Things	0,1%		
Cloud computing	0,1%		
Smart grids	0,0%		
	Legend		
	Low share		High share

Source: Balland, 2022 based on PATSTAT

2.2 Tech startups in the ecosystem fostering the green and digital transition

Technology startups represent key building blocks in the transition towards a more digital, green and resilient economic model. Entrepreneurial activity helps accelerating the diffusion of technologies in industrial ecosystems and startups that provide green and digital mobile solutions are relevant indicators of how the industrial ecosystem is transforming itself to reach environmental sustainability objectives.

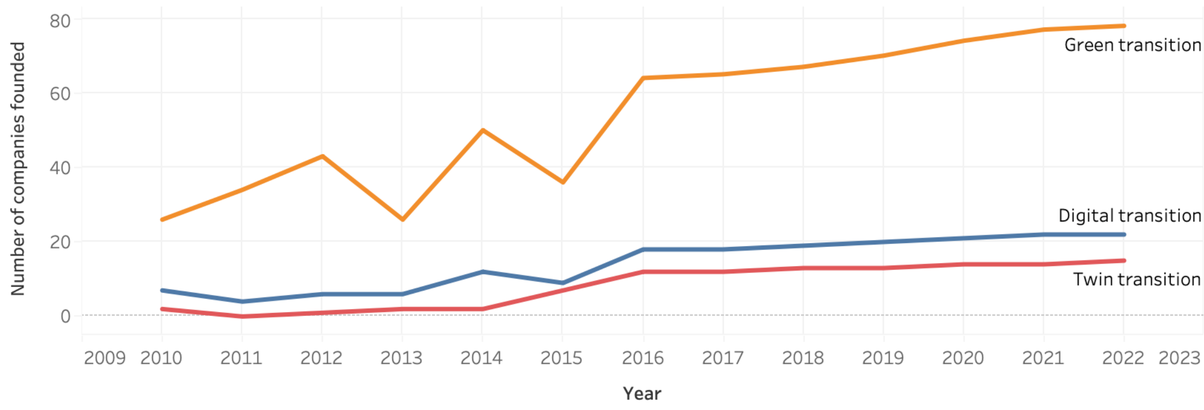
In this section, the analysis of technological and innovative startups is based on tech startups and companies active in the chemical and steel industrial ecosystem that have been sourced from the Crunchbase and Net Zero Insights database.[47] Net Zero Insights focuses on capturing sustainability driven startups and therefore covers widely the innovations developed in the context of the green transition, while Crunchbase collects data primarily on venture capital-backed tech companies. Digital and green technologies have been linked to startups within energy intensive industries, notably zooming in on startups active in the chemical and steel industries. More details on the selected industry tags and technologies can be found in Annex A, and the methodological report.

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

Figure 8 presents the creation of these startup tech companies specifically for the area of chemicals over time, covering the period from 2010 to 2022. Looking at the share of these companies that are active in the green, digital, and twin transition, the green transition is clearly leading the way in terms of number of companies founded across the overall period, with an increasing trend for those related to the area of chemicals. The digital transition is clearly present with a slowly increasing trend, while those tech startups active in both the green and digital transition also make up an increasing portion, highlighting the increasing importance of the twin transition.

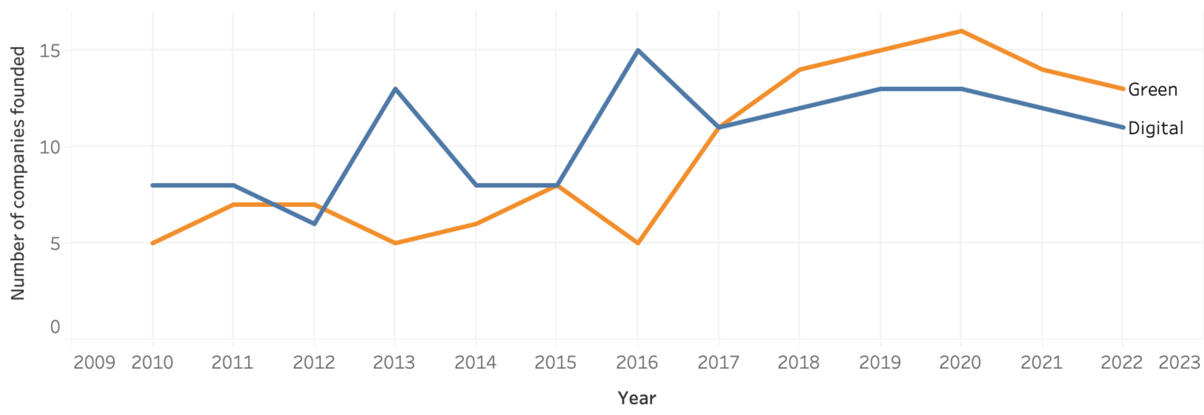
Likewise, Figure 9 presents the annual creation of steel startups in the EU27 from 2010 to 2022 as a key underlying part of the EII ecosystem. The importance of the green and digital transition is evident, however the importance of either trend has been dynamic from the period of 2010 to 2017. From 2017 onwards, the green transition took clear and continuing precedence over the digital transition, underpinning the need for greening of the overall industry. That being said, both the green and digital transition see a declining importance from 2020 to 2022, which can be related to the impact of both the COVID-19 pandemic and the Russian invasion of the Ukraine on the industry.

Figure 8: Annual creation of chemical startups in the EU27



Source: Technopolis Group, 2022, based on Crunchbase and Net Zero Insights data

Figure 9: Annual creation of steel startups in the EU27



Source: Technopolis Group, 2022, based on Crunchbase and Net Zero Insights data

Type of technologies

Building on the overall statistics of the chemicals and steel related tech startups indicated above, it is possible to further zoom in on the specific technologies in which these companies are active. This allows to give insight into which technologies are of greatest importance for the startups and their underlying business model.

Chemical industry

The technologies leading the green transition within the chemical tech startups, are recycling technologies (43.6%), advanced materials (22.9%) and low carbon technologies (7.2%) as depicted in Figure 10. Among the recycling technologies, startups are active in areas such as plastic recycling, including Repeats[48] a Dutch company that develops a recycling platform focused on recycling polyethylene plastic waste. Water recovery and recycling is an important technology including companies such as Captive Systems[49] who develop industrial water treatment technology including technologies for the removal and/or recovery of lipophilic substances, hydrocarbons and heavy metals. Catalyst recycling is also important for the chemical industry, as catalysts are fundamental to many chemical reactions. Beworm[50] is a German company developing a biocatalytic recycling process based on natural processes to decompose plastic waste into natural raw materials which can help reduce environmental impact. Within the area of advanced materials, technologies range from bio-based to nanotechnology with applications in new materials. Notable start-ups include Lignopure[51] and ChainCraft[52] who are using food waste to develop material alternatives. On low carbon technologies relevant for the chemicals industry, these can range from technological solutions that replace petroleum-based ingredients with non-food biomass products such as Afyren[53]to biocatalyst solutions that replace traditional fossil-based manufacturing with a cell-free technology, such as EnginZyme[54].

Among the digital technologies, advanced manufacturing makes up the greatest share at 8.3%, followed by 5.4% with micro- and nanoelectronics and photonics and Internet of Things (4.0%). Examples of companies active in the area of advanced manufacturing include those active in the area of 3D printing, such as vanPlestik[55], focussing on 3D printing of plastic waste, and Volatile innovation[56], specialising in nano and micro fibrous matrixes with applications in biomedicine, pharmaceuticals, food packaging and chemical engineering. In the area of IoT, an interesting example includes the startup AEInnova [57] who specialise in the development of battery-less and maintenance-free IoT devices that can be used specifically for monitoring machines in the chemical industry using heat, wind, or solar power.

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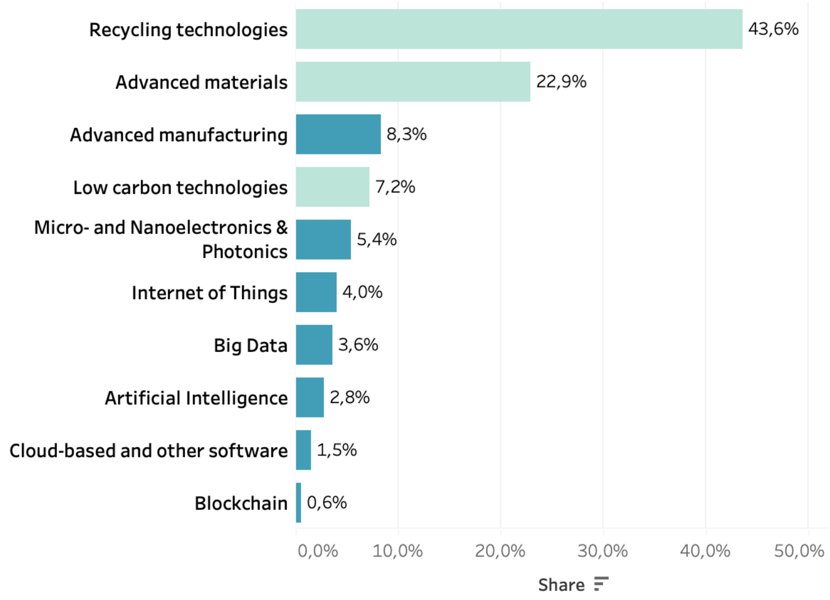
[48] See http://repeats-group.com
[49] See https://www.captivesystems.it/en/index.html
[50] See http://beworm.org
[51] http://www.lignopure.de
[52] https://chaincraft.com
[53] http://www.afyren.com
[54] https://enginzyme.com/about
[55] http://vanplestik.nl/en/about-us-2/
[56] https://volatileinnovation.com/services/
[57] https://aeinnova.com

Figure 10: Share of technologies used by chemical startups founded for the period 2010-2022



Source: Technopolis Group, 2022, based on Crunchbase and Net Zero Insights data

Steel industry

Zooming in on specific technologies active within the steel industry, we see in Figure 11 that the share of technologies used by steel startups founded in the period of 2010 to 2022 are dominated by recycling technologies (24.1%) in the green transition, followed by activities in other areas of the green transition namely advanced materials (6.1%), energy saving technologies (4.8%) and renewable energy technologies (4.4%).

Recycling technologies related to the steel industry include startups focussing on developing or enabling recycling processes or supply secondary raw materials. Companies include CleanSort[58] from Germany, who are developing recycling technologies for the metal industry that rely on advanced sensors and machine learning to enable highly efficient sorting and separation of scrap metals. In addition, Magsort[59] is a Finnish company that focusses on the application of magnetic separation technologies to distinguish especially metals and alloys in separation.

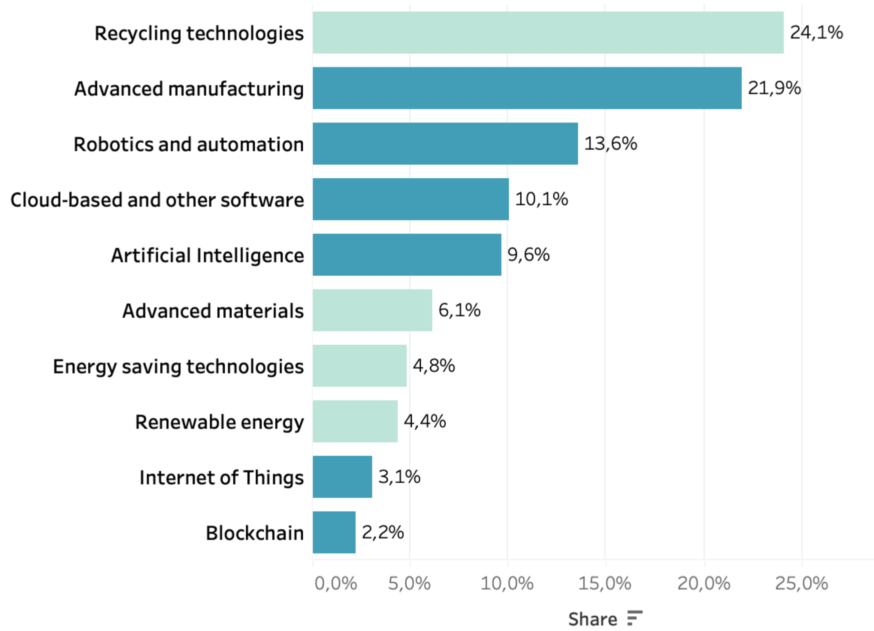
In the area of digital technologies, the main technologies making these up include advanced manufacturing (21.9%) and robotics and automation (13.6%) with some activities also related to cloud-based and other software solutions, and artificial intelligence, among others.

Within the area of advanced manufacturing, a large fragment of companies (N=27) focus on 3D printing technologies and their applications for steel and metal manufacturing. For example, Additive Works[60] is focussed on the development of software solutions for metal 3D printing. Other technologies include lithography-based metal manufacturing (LMM) with companies such as MetShape[61] relying on this technology to support prototyping, high-volume production, sintering services and finishing services.

[58] https://cleansort.de/en/technologie/
[59] http://www.magsort.fi/
[60] https://additive.works/
[61] https://www.metshape.de/home.html

In the area of artificial intelligence, a notable startup is active in both the green and digital transition, namely Smart Steel[62], who offers an AI based software solution that helps to improve the quality, as well as the energy demand of steel production in view of managing CO_2 efficiency.

Figure 11: Share of technologies used by steel startups founded for the period 2010-2022

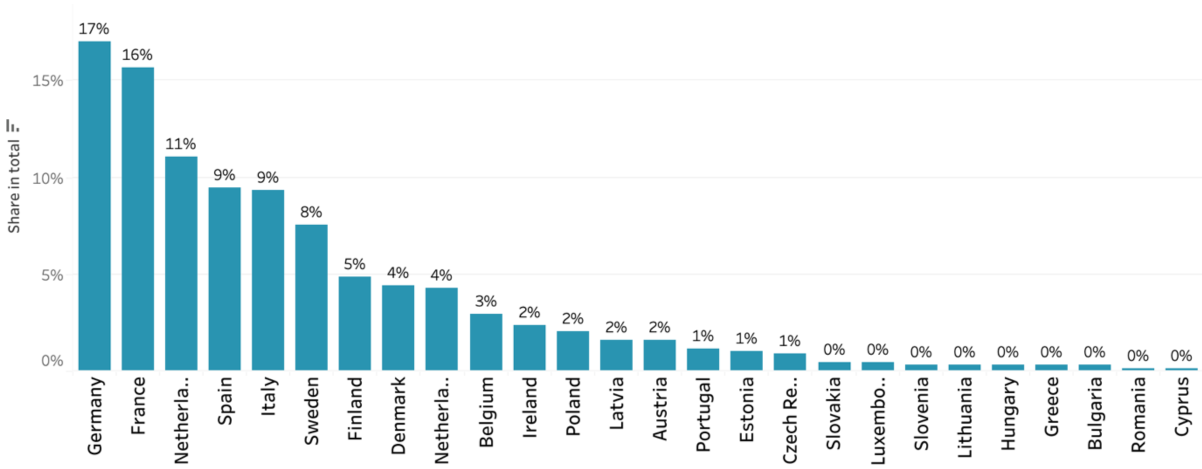


Source: Technopolis Group, 2022, based on Crunchbase and NetZeroInsights data

Country insights

The geographic element of the chemical and steel startups locations offers complementary insights. Figure 12 presents the number of chemical startups for the period between 2010 and 2020. Notably, Germany leads the way, with France, the Netherlands, Spain and Italy rounding out the top 5.

Figure 12: Share of number of Chemical startups per country

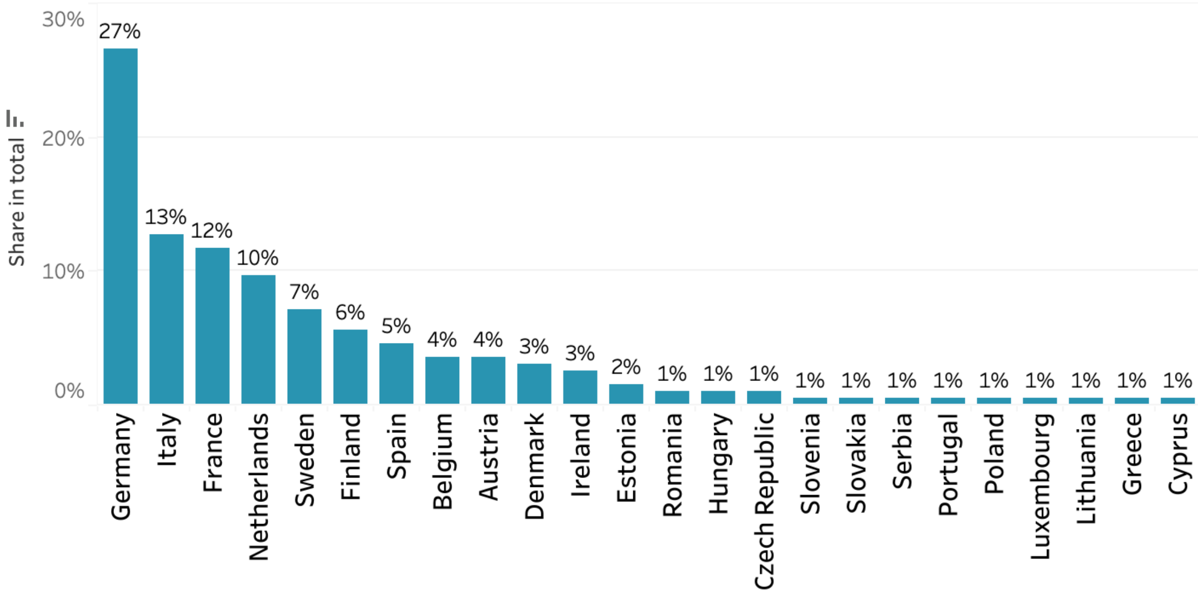


Source: Technopolis Group, 2022, based on Crunchbase and NetZeroInsights data

[62] https://www.smart-steel-technologies.com/

For the steel industry within the EII, the country distribution is slightly different, with Germany leading, followed by Italy, France, the Netherlands and Sweden as presented in Figure 13.

Figure 13: Share of startups per country



Source: Technopolis Group, 2022, based on Crunchbase and NetZeroInsights data

3. Uptake of green and digital technologies and circular economy practices

Key findings

A business survey and text mining of company websites was conducted as part of the project about the status in the uptake of digital and green technologies and related business models in SMEs operating in the energy intensive industries ecosystem.

The results reveal that **60.4% of SMEs respondents have increased their investments dedicated to the green transition and environmental sustainability** during the past five years, while 46.4% of the respondents invested between 5-9% of their revenue in green transformation on average annually. SMEs in the **energy intensive industries (EII) ecosystem adopted most easily the use of recycled materials and recycling technologies with a share of 20.4% and 20.2% respectively.** In addition, several SMEs responded that they are planning to adopt these two technologies (11% and 9% respectively). While energy-saving technologies are only the third solution adopted by SMEs, 60.5% of respondents cover between 20-50% of their total consumption with renewable energy. 16.8% of the respondents declare that they adopted circular design as green business model.

Companies operating in the EII industrial ecosystem are relatively stable in the number of environmental certificates issues over the last 5 years.

A different picture emerges when looking at the digital transformation of SMEs active in the EII industrial ecosystem. Only **36.61% of the survey respondents indicated that they had increased their investments dedicated to digital technologies over the past five years**, with 40% of respondents investing less than 5% of their revenue in digital technologies. The digital technologies that are most adopted by respondent SMEs are cloud technologies (29.1%) and online platforms (27.4%).

Technology centres active in the on energy intensive industries ecosystem in Europe are mostly located in Spain (14), France (9) and Germany (9). They **are key actors in the EII innovation ecosystems due to the services they offer, the technical expertise and their ability to steer collaboration among various types of actors in their ecosystems**.

With the objective to monitor the status in the uptake of digital and green technologies and related business models, this study adopted a mixed-method approach including a **business survey and text mining of company websites**. The survey was based on Computer Assisted Telephone Interviewing (CATI). The final sample included 8 987 companies in all industrial ecosystems and 1 464 interviews for the energy intensive industries ecosystem in particular. The mainstage fieldwork was conducted between 15 January and 31st May 2023. The survey respondents come from a mix of micro-enterprises (less than 10 employees), small enterprises (10-50 employees) and medium-sized enterprises (50-250 employees).

The results of other existing surveys have been also taken into account such as the Flash Eurobarometer 498 on SMEs, green markets and resource efficiency, and the ICT-usage in enterprises survey[63]. The different time of the field work for each survey can give some insights about progress even if the questions were not exactly the same. The Flash

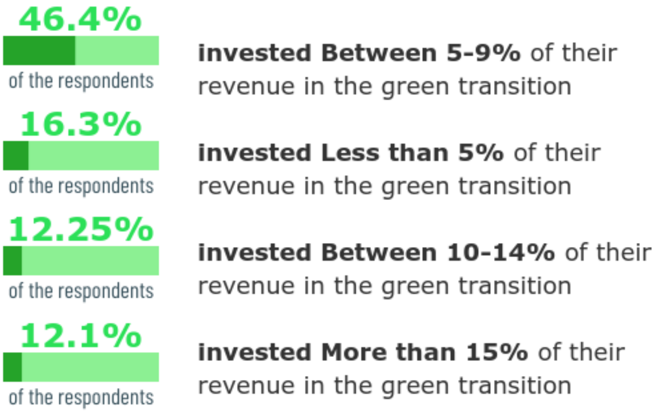
[63] https://ec.europa.eu/eurostat/cache/metadata/en/isoc_e_esms.htm

Eurobarometer 498's field work took place in November-December 2021. The last ICT usage survey results date from 2020.

3.1 Green transformation of SMEs

As part of the EMI survey, respondents were asked whether SMEs in the ecosystem **had increased their investments dedicated to the green transition** and environmental sustainability during the past five years, and **60.4% of the respondents answered** positively. Nonetheless, a further question was raised related to the percentage in terms of the revenue that SMEs invested in green transformation on average annually. The responses show that 46,4% **invested between 5-9% of their revenue** (see Figure 14).

Figure 14: Share of revenue invested in green transformation by SMEs in the EII ecosystem on average annually



Source: Technopolis Group and Kapa Research, 2023

Despite this first positive news, the Flash Eurobarometer found that in 2021, **only 11% of the SMEs surveyed in energy intensive industries had a concrete strategy in place to reduce their carbon footprint and become climate neutral** or negative, and only 11% was planning to prepare one.

The detailed survey results demonstrate that **SMEs in the ecosystem have been most active in the use of recycled materials and recycling technologies**. Seen the scarcity of several raw materials, recycling has a great potential to improve Europe's resource efficiency. In addition, recycling often requires less energy compared to virgin materials, leading to energy-savings which has become important since the start of soaring energy prices in 2021. Energy-saving technologies is mentioned as third with 19,4 % of SMEs active in energy intensive industries to adopt these technologies. The least cited green technologies include carbon capture and hydrogen, although the use of hydrogen in energy intensive industries has a lot of potential to contribute to the transition into a net-zero emission era (see Figure 15).

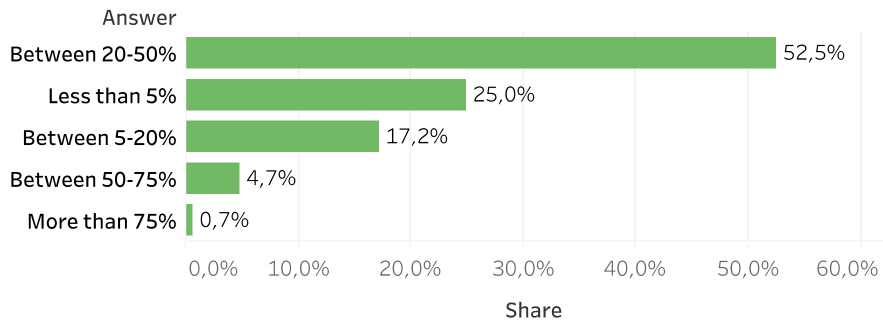
Figure 15: Adoption of green technologies in the energy intensive industries ecosystem

Green technologies	Answer: Already using	Answer: Planing to adopt
Recycled materials	20,4%	11,0%
Recycling technologies	20,2%	9,0%
Energy-saving technologies	19,4%	2,0%
Clean production technologies	17,6%	5,0%
Renewable energies	16,9%	2,2%
Advanced sustainable materials	16,5%	4,0%
Additive manufacturing	11,5%	2,0%
Biotechnology for sustainability	10,5%	3,0%
Carbon capture technologies	9,8%	1,0%
Hydrogen	8,7%	3,0%

Source: Technopolis Group and Kapa Research, 2023

Looking at the share of recycled materials which is effectively used by SMEs in their products/production shows that **52.5% of the respondent SMEs declare to use between 20 to 50% recycled materials.**

Figure 16: What is the share of recycled materials that you use within your products/production? (Share of respondents in EII that use recycled materials)

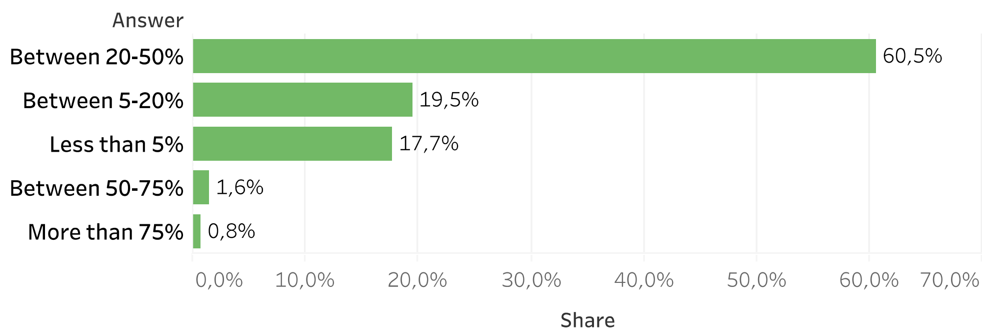


Source: Technopolis Group and Kapa Research, 2023

Renewable energy

The results of the survey indicate that 60.5% of the respondents cover between 20-50% of their total consumption with renewable energy. This is in line with the findings from the Flash Eurobarometer in 2021, which identified that 19% of the SMEs use predominantly renewable energy sources.

Figure 17: Share of renewable energy use within total energy consumption by EII SMEs surveyed in the EU27

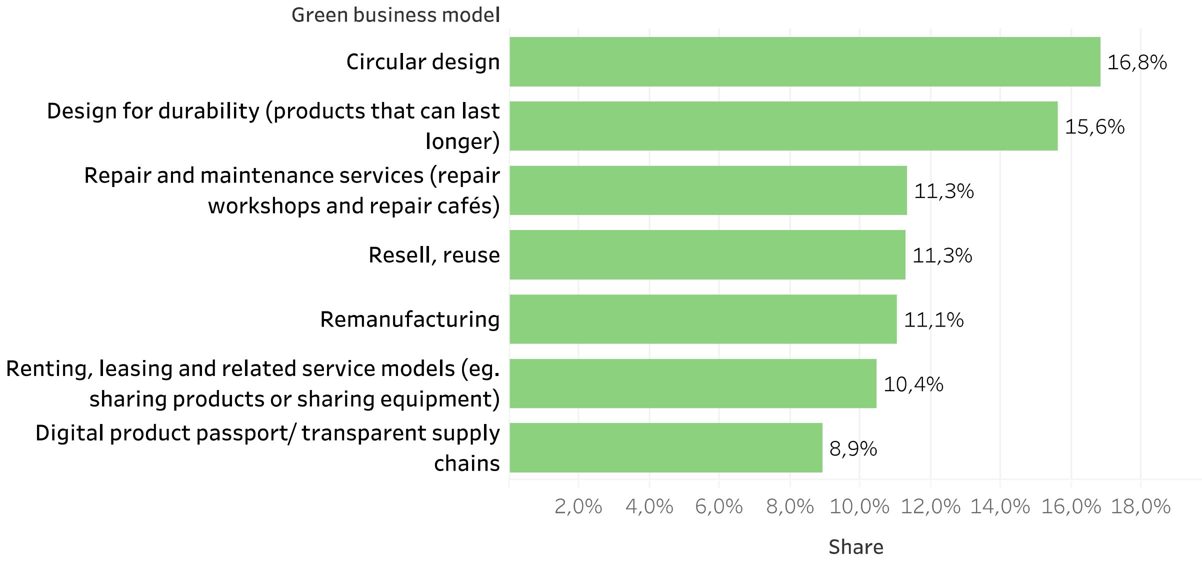


Source: Technopolis Group and Kapa Research, 2023

Circular business and service models

SMEs in the EII ecosystem were also surveyed about the **adoption of green business models** and non-technological solutions. The results indicate that 16.8% of the respondents adopted circular design and 15.6% design for durability models. Renting, leasing and related service models and digital product passport/transparent supply chains are green business models that are less adopted by SMEs. The Transition Pathway for the Chemical Industry also refers to chemical leasing as a potential new business model that can address the over-consumption of chemicals by charging customers based on functions performed by the chemicals rather than by the volume of chemicals purchased.

Figure 18: Adoption of green business models and non-technological solutions in EII in the EU27

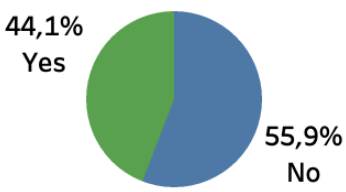


Source: Technopolis Group and Kapa Research, 2023

Environmental standards

When asked about the certification on any environmental standards, it is **44.1% of the respondents indicated that they had been certified** (see Figure 19) by a third party.

Figure 19: Share of survey respondents indicating that they have obtained a third-party verified environmental certificate

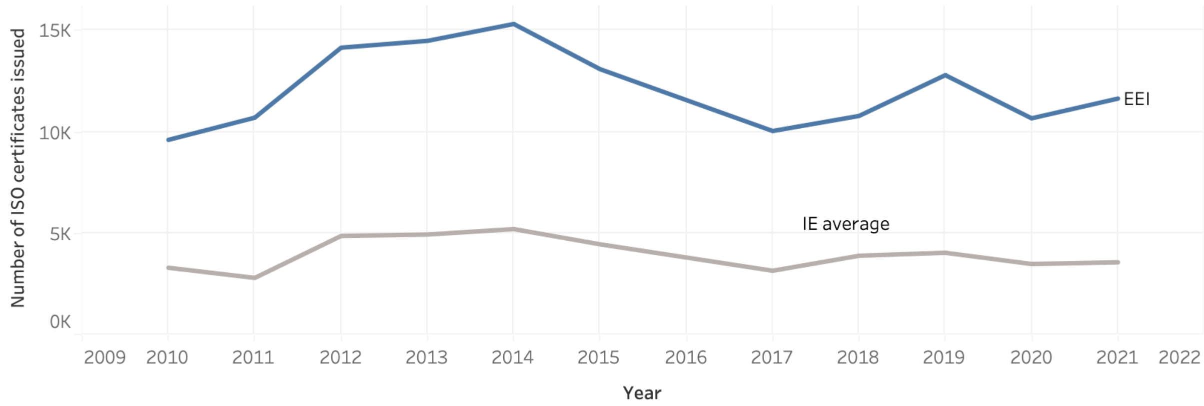


Source: Technopolis Group and Kapa Research, 2023

In terms of **environmental certificates,** there are a number of certificates and standards that aim to reduce energy consumption, improve energy efficiency, and promote sustainable energy practices. Particularly, **ISO 14001** includes a set of standards that any company can follow to implement an effective environmental management system. By adopting the good practices suggested by the standards, firms can substantially reduce their environmental footprint. The number of environmental certificates issued in the industry indicates the progress towards the application of environmentally friendly business practices and production methods. For the purposes of this report, ISO data were accessed via the ISO survey of certifications to management system standards[64].

The analysis of the data as depicted in Figure 20 shows that companies operating in the EII industrial ecosystem are relatively stable in the number of environmental certificates issues over the indicated period. Since reaching the peak in 2014, the number of companies using environmentally friendly standards has steadily decreased, falling slightly above 2010 values.

Figure 20: Number of environmental certificates issued

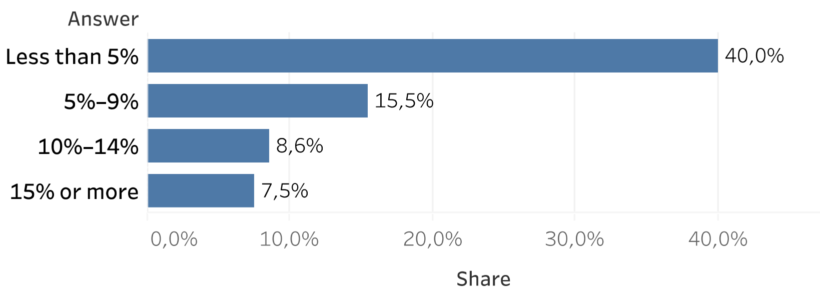


Source: Technopolis Group, 2022, based on ISO

3.2 Digital transformation of SMEs

Digital transformation has been less of a concern for SMEs in the EII industrial ecosystem compared to green objectives as analysed above, given the fact that only **36.61% of the survey respondents indicated that they had increased their investments dedicated to digital technologies over the past five years**. A further question was related to the percentage in terms of revenue that SMEs had invested in digital transformation on average annually. The responses show that **the majority of respondents (40%) invested less than 5% of their revenue** in digital technologies, which is relatively low.

Figure 21: Share of revenue/income invested in digital transformation in the EII on average annually



Source: Technopolis Group and Kapa Research, 2023

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

The level of adoption of specific digital technologies relevant for the ecosystem is presented in Figure 22. The results demonstrate that **cloud technologies and online platforms** are the two digital technologies that are most adopted by respondent SMEs active in EII. Big data, artificial intelligence and IoT are less adopted, respectively 14%, 12.7% and 11.9%, but there is a higher tendency to adopt them in the near future. DIGITALEUROPE's roadmap for Europe's energy ecosystem digital transformation proposes a KPI to capitalise on digital technologies to improve energy efficiency by 30% by 2025.

Figure 22: Adoption of digital technologies by SMEs in the EII following the EMI survey results

	Answer	
Technology	Already adopted	Planning to adopt
Cloud technologies	29,1%	5,0%
Online platform	27,4%	2,0%
Big data	14,0%	8,0%
Artificial Intelligence	12,7%	4,0%
IoT	11,9%	6,0%
Robotics	9,3%	2,0%
Digital twin	7,5%	1,0%
AVR	6,6%	1,0%
Blockchain	4,0%	

Source: Technopolis Group and Kapa Research, 2023

Cloud technologies

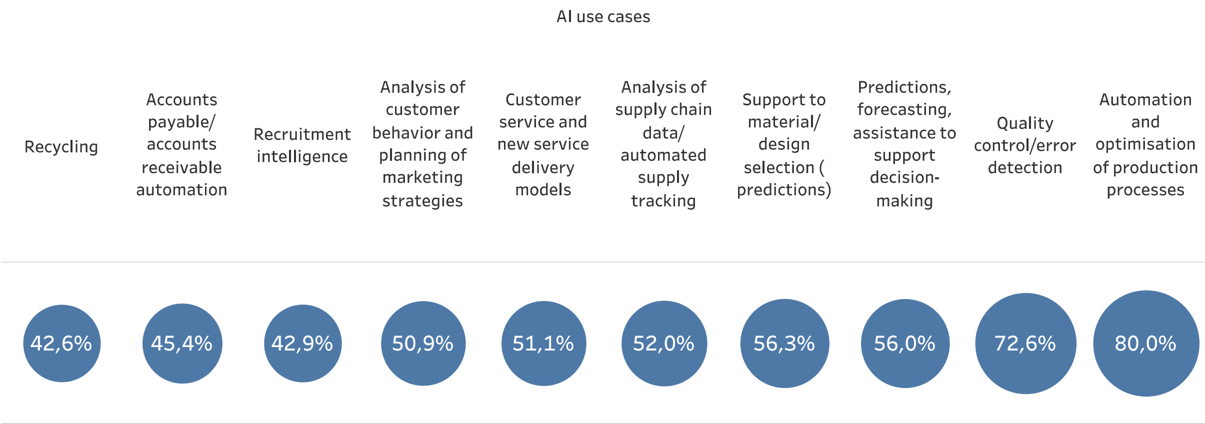
According to Eurostat statistics[65] 36.4% of the companies apply cloud computing services in EII in EU-27. Denmark and Ireland are leading with 70.8% and 68.6% respectively.

Big data and AI

Areas where big data and artificial intelligence have been focused on along the EII industrial value chain include automation and optimisation of production processes, quality control/ error detection, and predictions, forecasting, assistance to support decision-making (see Figure 23).

[65] https://ec.europa.eu/eurostat/databrowser/view/ISOC_CICCE_USEN2__custom_7403763/default/table?lang=en

Figure 23: Use cases of AI among EII SMEs

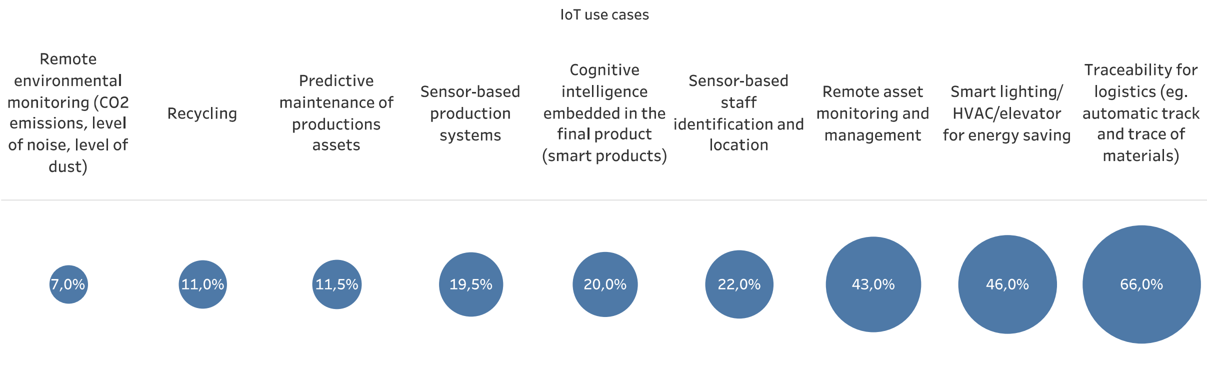


Source: Technopolis Group and Kapa Research, 2023

Internet of Things

Internet of Things is used by 11.9% of the respondent SMEs. IoT is often used for traceability purposes related to logistics e.g. track and tracing of materials. It is also applied for smart lighting and remote asset monitoring and management.

Figure 24: Use cases of Internet of Things (share of companies within those that already use IoT)



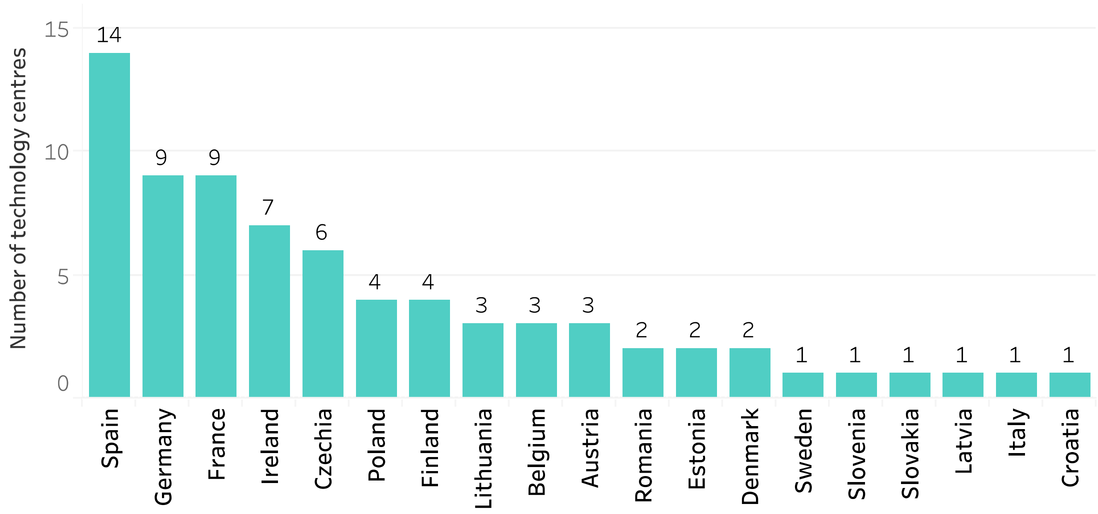
Source: Technopolis Group and Kapa Research, 2023

3.3 Technology centres

Innovation actors are at the core of industrial ecosystems and gathering and sharing information about them in a structured way is crucial to detect gaps, improve collaboration, foster innovation and strengthen innovation ecosystems. The Technology Centre Mapping comprises information on technology centres that are key actors in innovation ecosystems due to their technical expertise and their ability to bring together and steer collaboration among various types of actors in their own ecosystems and beyond.

Figure 25 presents the number of technology centres (TCs[66]) that are active in the energy intensive industry industrial ecosystem per European country and shows that Spain (14) is the country with the highest number of technology centres in Europe, followed by France (9), Germany (9) and Ireland (7). These countries might host additional technology centres active in the energy intensive industry industrial ecosystem, which are currently not registered to the technology centres mapping.

Figure 25: Technology centres per country – energy intensive industries



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

The following examples serve to illustrate the activities and scope of technology centres active in energy intensive industries, their links with the broader ecosystem as well as examples of recent activities in which they are involved. The examples are randomly chosen to present the information that can be found on the Technology Centre Mapping. They include the following three cases EnergyLab (ES), Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT (DE), and TNO (NL).

Box 1 : Example Technology Centre: EnergyLab (ES)

Name of the Centre	**EnergyLab (ES)**
Location and scope	

[66] ATI Technology Centres are public or private organisations carrying out applied research and close-to-market innovation (Technology Readiness Levels TRL 3 to 8, not necessarily the whole range) in Advanced Technologies for Industry.

EnergyLab is a private non-profit technology centre that was created in 2008 as an initiative of the regional government of Galicia, in the north of Spain. In 2014, the Ministry of Economy and Competitiveness turned EnergyLab into a National Technological Centre. The governing body of the Centre is based on a board formed by public entities (the Energy Institute of Galicia, University of Vigo, University of Santiago de Compostela and University of Coruña), and private entities (Philips, Inditex, Naturgy and Repsol, among others).

The aim of EnergyLab is to develop innovative projects which implement energy efficiency by reducing the environmental impacts of its activities. To carry this out, EnergyLab focuses on the following R&D&I lines: Industry, Urban Ecosystems, Bioenergy, and Energy Technologies.

EnergyLab is part of two international networks: the ReBiBiR Biomass Network (Iberoamerican Network of Biomass and Rural Bioenergy Technologies) of CYTED and the Biomass-AP Cross-Border Network. It is also member of the Technological Platform for the Protection of the Coast and Marine Environment (Pt-PROTECMA) and of ATIGA (The Galician Technological Alliance). At European Level, the centre is member of the SPIRE and PCTP technology platforms.

Main services and equipment

EnergyLab provides services to identify, implement and boost processes, technologies and products that improve energy performance and sustainability.

The services offered are divided into the following categories:

- **Diagnosis and Energy Management**, which implies pre-audit and detailed energy audits, implementation of platforms to monitor energy consumption and technical assistance for the implementation of the ISO 50001 standard, among others.
- **Simulation services** by building energy simulation, Computational Fluid Dynamics (CFD) simulation, and life-cycle analysis (LCA).
- **Laboratory services** specialised in characterisation such as the Biomass, Biogas and Mobility Lab.

EnergyLab offers other services such as **training courses** for EVO certification level, and for Energy Auditors.

Recent projects related to the green and digital transition in energy intensive industries

- **EU-NETS** (February 2022-January 2025): EU-NETS is an Erasmus+ project that aims to offer professionals tools through a new training itinerary, in order to develop capabilities to play an active role in managing Energy Communities and dealing with the green transition.
- **Inertimar II** (December 2021- October 2023): The aim of the project is to develop and validate a sustainable and effective anisakis extermination system on board in a fishing vessel, which will make use of the thermal energy generated by the ship's engine and will reduce electricity consumption by 75%.
- **APROAVI** (July 2022-October 2024): This project is co-financed by the European Innovation Association (EIA), and the European Agricultural Fund for Rural Development (EAFRD) within the framework of the Rural Development Program (PDR) of Galicia 2014-2020. The objective is to enhance the competitiveness of poultry farms through the recovery of poultry manure along with other organic waste, fostering its conversion into renewable energy (biogas and pyrolysis gas) and fertilizers based on digestate and biochar.

Source: Advanced Technologies for Industry Technology Centre Mapping, 2023 and EnergyLab, 2023 https://energylab.es

Box 2: Example Technology Centre: Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT (DE)

Name of the Centre	Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT (DE)
Location and scope	
Fraunhofer UMSICHT, was founded in June 1990 in the city of Oberhausen as a non-profit technical and scientific institution and as one of the 74 institutes and research units of the Fraunhofer-Gesellschaft. Nowadays the institute has sites in Oberhausen, Willich, and Sulzbach-Rosenberg. The Centre develops innovative, industrially feasible technologies, products and services for the circular economy and bring them to application. The focus is on the balance of economically successful, socially equitable and sustainable developments. Fraunhofer UMSICHT has strategic collaborations in Kuwait, with the University of Alberta in Edmonton/Canada and with the University of Birmingham, UK. It also cooperates with several countries within the framework of industrial and start-up projects: India, Indonesia, Chile, Vietnam, Korea, China, Mozambique, and Colombia.	
Main services and equipment	
Fraunhofer UMSICHT offers services in its different Business Units: Polymer Materials, Chemistry, Environment, Biomass, and Energy. Concrete services in Energy are provided, related to: • Energy systems analysis and design (e.g. municipal storage systems, modelling of energy load balancing technologies) • Technical development (e.g. thermal, electrical, and chemical energy storage technologies, pilot plant construction, sue of geothermal energy) • Studies, consulting (e.g. energy storage systems, flexibility of CHP systems) Fraunhofer UMSICHT also conducts studies and offer consulting services focused on developing strategy and scenarios, customer specific calculation, and management to decentralise energy systems.	
Recent projects related to the green and digital transition in energy intensive industries	
• Aerogel insulation material for the construction industry and lightweight design (April 2021- March 2024): The aim of the "**Aerolight**" project is to develop a cost-effective manufacturing process for aerogels and new formulations. Aerogels are to be made usable in various applications in the field of thermal insulation systems, lightweight concretes and sandwich elements for facades and roof elements. • **ElkaSyn**, Energy-efficient electrosynthesis of alcohols (August 2019-July 2022): The aim of the project is the direct production of alcohols from CO2 – by means of electrochemical reduction. This electrolysis is operated under technical-economic conditions. • **ELuStat** (January 2019 to April 2022): Within the framework of the ERDF funded ELuStat, an iron-air battery stack is created as a stationary energy storage system. It compensates the fluctuating power generation by photovoltaic or wind energy plants and at the same time contribute to the reduction of CO2.	

Source: Advanced Technologies for Industry Technology Centre Mapping, 2023 and Fraunhofer UMSICHT , 2023 https://www.umsicht.fraunhofer.de/

Box 3: Example Technology Centre: TNO (NL)

Name of the Centre	TNO (NL)
Location and scope	
TNO is an independent research organisation running since 1932 and which has a staff of 3400 professionals. The mission of TNO is to strengthen the competitiveness of companies and the wellbeing of the society by linking people and knowledge to generate sustainable innovations. To reach this purpose, TNO focuses on transitions in five social themes: • Energy, for faster progress towards a low-carbon energy system; • Industry, for a strong, internationally competitive business community; • Healthy Living, for a fit, healthy, and productive population;	

- Defence & Security, for decisive action in an uncertain world;
- Urbanisation, to innovate for dynamic urban regions.

TNO works with public authorities, companies, and other organisations on the following sectors: Energy, SME, Automotive, Building and Construction, Electronics, Finance, High Tech Industry, Logistics, Maritime, Government Bodies, Recycling and waste, Telecommunications, and Healthcare.

Main services and equipment

TNO offers general services:

- **25 labs** working in different sectors. It has three labs related to eenergy: The Geothermal Energy Lab, the Solar Lab, and the Energy Storage Platform.
- A **Tech Transfer Programme**, which accelerates the market launch of technologies and innovations.
- A **service for patents and licenses** for protecting the intellectual property.

TNO also provides concrete services related to energy:

- - Assessing the sustainability of wind turbines and the approval of their launching to the market.
- **- Trainings, and webinars** in the field of hydrogen, monitoring the performance of energy use and making a diagnosis for builders, developers, and end users.
- TNO is developing an automatised and digitalised maintenance service of wind turbines.

Recent projects related to the green and digital transition in energy intensive industries

- **Thermochromic coatings, saving energy through coated windows**: The objective of this project is to apply special coatings to windows to save energy while heating and cooling buildings. The coating, developed together with Brightlands Materials Centre, makes use of the sun's thermal radiation when heat is needed, keeping the heat in during winter and out in summer. The switch from one mode to another is fully automatic, thanks to the thermochromic coating.

- **Cold baked brick**: TNO has created an innovative process for producing a brick that does not need extremely high temperatures. The production process of bricks usually consists of heating clay to 1000 to 1200 degrees Celsius. The new process uses an (alkali) activator, where the temperature is between 20 and 50 degrees Celsius. This can be translated in energy savings for the producer.

- A 'smart window' with energy savings potential developed by TNO and partners in the Interreg project **Sunovate**, performs successfully in real world conditions according to preliminary pilot results. The window is designed to automatically switch between blocking heat from the sun and letting it pass. It is optimised to reduce energy consumption in moderate climates.

Source: Advanced Technologies for Industry Technology Centre Mapping, 2023 and TNO, 2023 https://www.tno.nl/

4. Investment and funding

Key findings

Substantial R&I investments are needed across the energy intensive industries to shift to low-carbon and circular production processes and to reach the European Green Deal emission targets. Low-carbon technologies (such as carbon capture, biomass and hydrogen use) needed for the transition are typically **more expensive** than fossil fuel-based production pathways and high investments are required to move such technologies from early phases of development to commercialisation. The EII ecosystem is performing better than average compared to the other ecosystems in terms of investments related to the **green transition.** At the same time, with regard to investments related to the **digital transition**, the EII ecosystem is in the middle to lower end compared to the other industrial ecosystems. Based on R&D&I investments, **EU27 companies are focussing more on green technology investment** in the energy intensive industries industrial ecosystem with over €48 bn in investments from 2017-2020.

Integrated production of hydrogen with low carbon footprint in the chemicals industry is leading investments with €19.6 bn of investments, followed by electrification (€11.4 bn) and non-conventional energy sources in process industry including carbon capture and use (€11.1 bn) for the observed regions for the energy intensive industries industrial ecosystem.

Chemical startups have received a total of EUR 2.1 billion from 2010 to 2022. There has been a strong increase in private equity and venture capital investment since 2010. Notably, access to early venture capital (early development) has sharply increased since 2015, achieving €169 m in 2021.

As regards digital technologies, companies developing advanced manufacturing techniques and micro- and nanoelectronics and photonics have been the most successful among investors, however collectively not gathering as much interest as the green transition technologies.

In the steel industry, startups developing digital and green solutions have received a total of €5.72 bn since 2010. The green transition is dominated by investments in **renewable energy technologies, followed by advanced materials and recycling technologies**. Green driven startups have gathered the majority of the funding, reaching a total of EUR 5.75 billion.

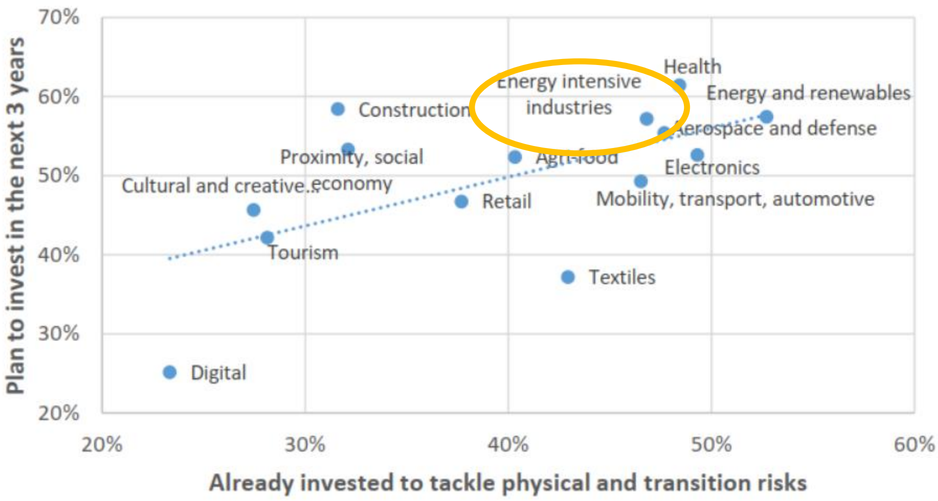
Zooming in on the digital technologies, a total of €124 m has been invested, with a sharp increase since 2018. Investment directed towards companies developing **advanced manufacturing reached a total of €78 m** for the considered period (2010-2022). Most of this funding was raised by companies focused on 3D printing, indicating a consistent interest of investors in these technologies.

In terms of foreign direct investment, outward EU27 investments from EU27 countries are considerably higher than the intra EU and foreign direct investment into the EU27 over the observed period from 2010 to 2022 with a declining trend over the observed period. Inward investment in EU27 shows a slight increase over the overall period, while intra EU27 remains stable.

Substantial R&I investments are needed across the energy intensive industries to shift to low-carbon and circular production processes and to reach the European Green Deal emission targets. Indeed, low-carbon technologies (such as carbon capture, biomass and hydrogen use) needed for the transition are typically **more expensive** than fossil fuel based production pathways and high investments are required to move such technologies from early phases of development to commercialisation.[67] Moreover, investments in energy savings or emission reductions do not offer the **same, immediate returns** as other investments, and often first require **substantial investments in infrastructure** (e.g., grid reinforcement of electricity networks, CO_2 and hydrogen pipelines), which may be difficult and unattractive for individual companies to realise. This raises the question of who should bear these required investments. For instance, governments could consider financing the initial infrastructure and ask users to pay for the services.[68] Another mechanism to drive investments towards low-carbon technologies would be a **CO_2 price signal**, improving returns on investments in green infrastructure and technologies. Here it would be important to secure competitiveness and avoid carbon leakage.

Nevertheless, the Annual Single Market Report (2022)[69] highlights that the EII ecosystem is performing better than average compared to the other ecosystems in terms of investments related to the **green transition** (see Figure 26). Particularly, close to 50% of the EU firms in the ecosystem have already invested in efforts to mitigate the impact of physical and transition risks and reduce carbon emissions. Moreover, close to 60% have plans to make such investments in the next three years, which is higher than the percentage of firms across all industrial ecosystems. At the same time, with regard to investments related to the **digital transition**, the report[70] highlights that the EII ecosystem is in the middle to lower end compared to the other industrial ecosystems (see Figure 27). Roughly 50% of the firms in the ecosystem have invested in digitalisation as a response to the COVID-19 crisis and almost 60% are planning investments in the long term.

Figure 26: Investment plans to tackle climate change impact, by industrial ecosystem



Source: European Commission 2022, Annual Single Market Report and sources therein

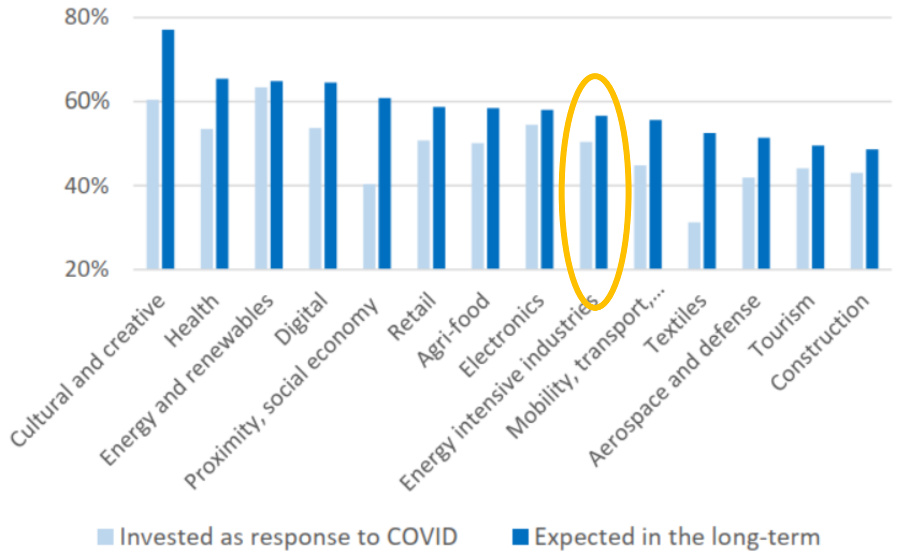
[67] SWD(2021) 277 final. For a resilient, innovative, sustainable and digital energy-intensive industries ecosystem: Scenarios for a transition pathway. https://ec.europa.eu/docsroom/documents/47059/attachments/1/translations/en/renditions/native

[68] European Parliament, Directorate-General for Internal Policies of the Union, Bruyn, S., Jongsma, C., Kampman, B.et al., Energy-intensive industries – Challenges and opportunities in energy transition : in-depth analysis, European Parliament, 2020, https://data.europa.eu/doi/10.2861/427814

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

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

Figure 27: Digital investment and long-term investment expectation (share of firms in %), by industrial ecosystems



Source: European Commission 2022, Annual Single Market Report and sources therein

Cefic[71] indicates that **capital investments in the chemical sector** in EU27 have increased overall from 2010 to 2021 to reach a value of €26.5 bn.[72] As a comparison, NAFTA[73] reached €28 bn and China €109 bn of capital investments in 2021. With that, the share of EU27 global chemical investments decreased over the years.[74] The largest chemical sectors in the EU27 in terms of investments were basic inorganics sectors (industrial gases, fertilisers, other inorganics), petrochemicals and polymers.[75]

4.1 R&D&I investments

Information on R&D&I investments allow to gauge the degree of market competitiveness of the supply and adoption of technologies in certain industrial ecosystems based on the headquarters of the location of a given company, while at the same time providing intelligence on the areas of industrial R&D&I investment. An ongoing study on "Support to Assessment and Monitoring of Industrial Research, Innovation and Technologies in the field of circular economy industries" on the uptake of circular technologies captures information on companies operating in select industries (through ORBIS and Dealroom) based on NACE codes and technologies (through patents and Technote) as well as investments in companies based on investments related to specific technologies identified through web announcements of the companies from Technote (web scraping). As result, data presents the R&D&I spending of companies active in the selected technology areas.[76]

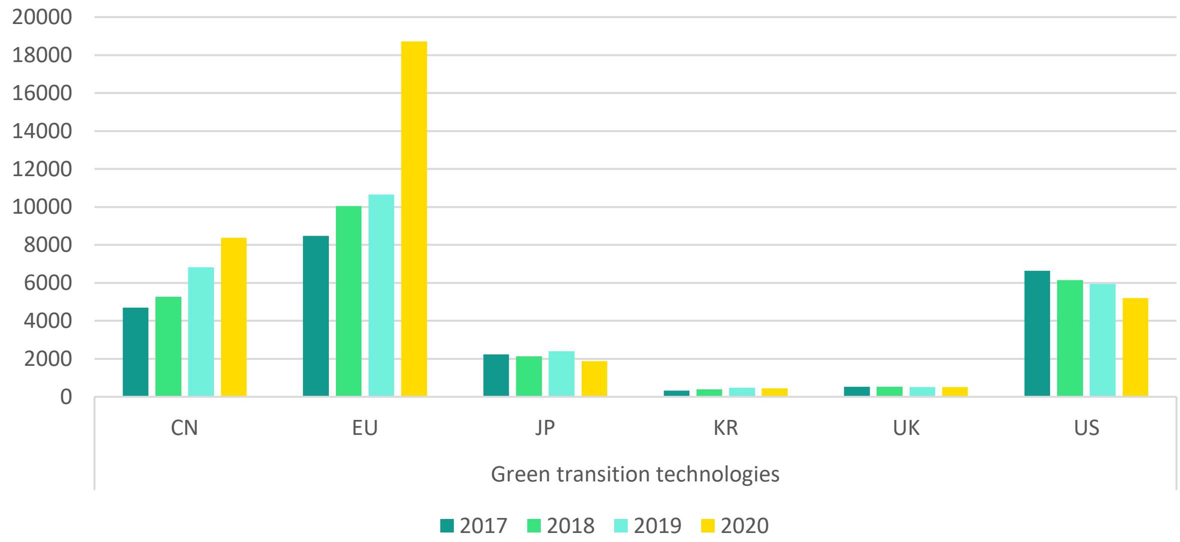
[71] www.cefic.org
[72] CEFIC (2023) The European Chemical industry Facts and Figures 2023 https://cefic.org/app/uploads/2023/03/2023-Facts-and-Figures.pdf Accessed on 8 November 2023
[73] North American Free Trade Agreement
[74] https://cefic.org/a-pillar-of-the-european-economy/facts-and-figures-of-the-european-chemical-industry/capital-ri-spending/
[75] https://cefic.org/a-pillar-of-the-european-economy/facts-and-figures-of-the-european-chemical-industry/capital-ri-spending/
[76] The data were made available through the contract: "Support to Assessment and Monitoring of Industrial Research, Innovation and Technologies in the field of circular economy industries (CEI) and of other industries in relation to the European Green Deal and the green transition.

The energy intensive industries industrial ecosystem is being used to pilot an exploratory analysis, together with the construction industrial ecosystem, into the use of data from this ongoing study for monitoring industrial ecosystems. Positioned next to the other data sets on investments and funding, this R&D&I data provides a complementary view as compared to the venture capital data analysis, as well as foreign direct investment and public procurement data, focussing on the early-stage R&D&I perspective.

EU27 companies are focussing more on green technology investment in the energy intensive industries industrial ecosystem with over €48 bn in investments from 2017-2020. The trend, as depicted in Figure 28, from 2017-2020 is increasing for green technologies supporting the green transition notably in the EU-27. Looking at world regions, the EU27 is clearly dominating the R&D&I investment landscape, with increasing trends also observed in China. Investment levels in Japan, Korea and the United Kingdom are steady, with a decreasing trend in the US over the indicated period.

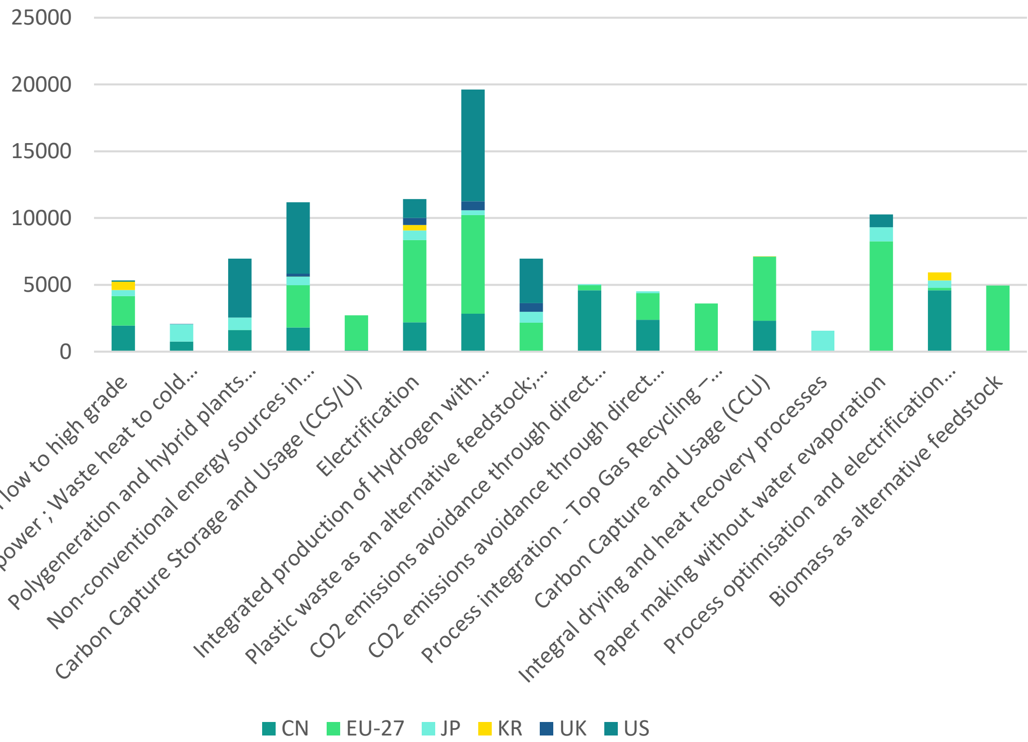
In order to understand which green technologies are underpinning the global green technology trends, Figure 29 presents the total R&D&I investments across the EU-27, China, South Korea, Japan and the US over the period of 2017-2020. Integrated production of hydrogen with low carbon footprint in the chemicals industry is leading investments with €19.6 bn of investments, followed by electrification (€11.4 bn) and non-conventional energy sources in process industry including carbon capture and use (€11.1 bn) for the observed regions for the energy intensive industries industrial ecosystem.

Figure 28: R&D&I investments of companies involved in the technologies related to the EII industrial ecosystem by world region (2017-2020)



Source: Support to Assessment and Monitoring of Industrial Research, Innovation and Technologies in the field of circular economy industries, 2022, based on ORBIS, Dealroom, PATSTAT and Technote

Figure 29: R&D&I investments of companies involved in the technologies related to the EII industrial ecosystem from 2017-2020



Source: Support to Assessment and Monitoring of Industrial Research, Innovation and Technologies in the field of circular economy industries, 2022, based on ORBIS, Dealroom, PATSTAT and Technote

4.2 Venture capital and private equity investments

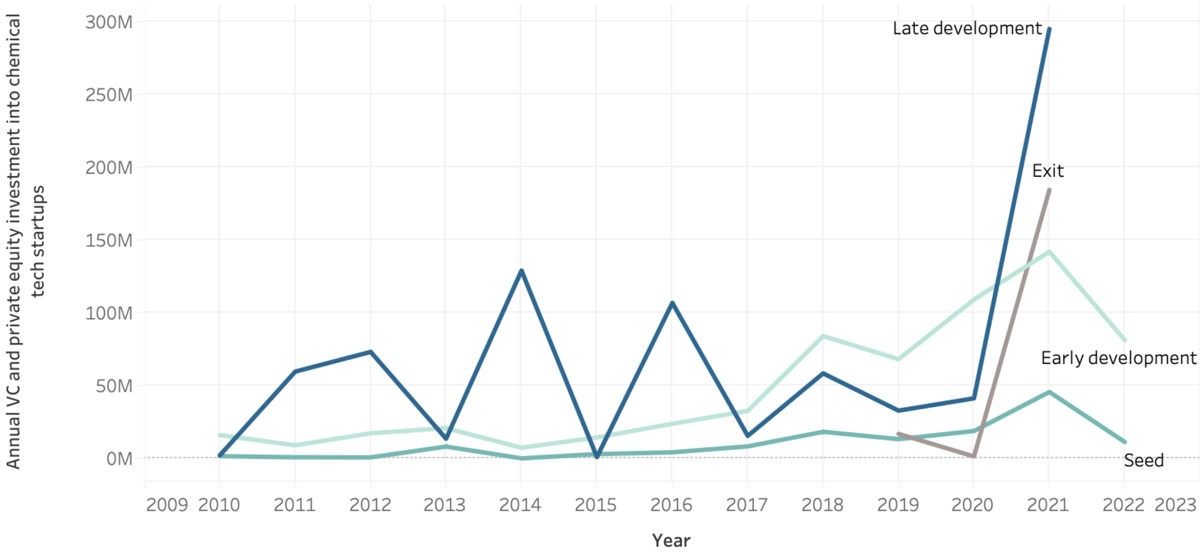
The scale of venture capital (VC) and private equity investment in EII tech companies specifically in the chemical and steel industries that focus on digital and green technologies and business models has been calculated using a combined dataset from Net Zero Insights and Crunchbase sources. The investment figures presented in this section refer only to the funding rounds where a value has been disclosed. Those investments for which no values were published, are therefore not included in the analysis.

Chemical industry

Resulting from the indicated data set, chemical startups have received a total of €2.1 bn from 2010 to 2022. There has been a strong increase in private equity and venture capital investment since 2010. Figure 30 presents the annual funding in chemical tech companies since 2010 by funding stage. Seed-stage funding has been steadily increasing since 2014, with an average annual growth of 65% between 2015 and 2021. This showcases a positive financial interest for newly created chemical startups. Similarly, access to early venture capital (early development) has sharply increased since 2015, achieving €169 m in 2021. On the other hand, access to late-stage venture capital has been fluctuating over the years until 2017, the year in which access to this type of funding started to steadily grow. In 2022, late funding reached a total volume of €302 m.

Regarding funding on exit[77], access to this funding is only recorded after 2019 and hence no data is available before that time.

Figure 30: Annual funding in Chemical tech companies since 2010



Source: Technopolis Group calculations based on Crunchbase and Net Zero Insights, 2023

Looking at the core technologies capturing funding, green chemical startups have accessed a total of €1.90 bn, compared to €282 m captured by digital startups.

Startups developing recycling technologies have the greatest access to funding, with an average annual growth rate of 69% since 2016, capturing €229 m alone in 2022. This indicates an increasing financial interest towards recycling solutions, in particular to address plastic pollution. An example is the plastic recycling company Ioniqa Technologies[78], founded in 2009, that has gone through three VC rounds reaching a total of €42 m in 2022.

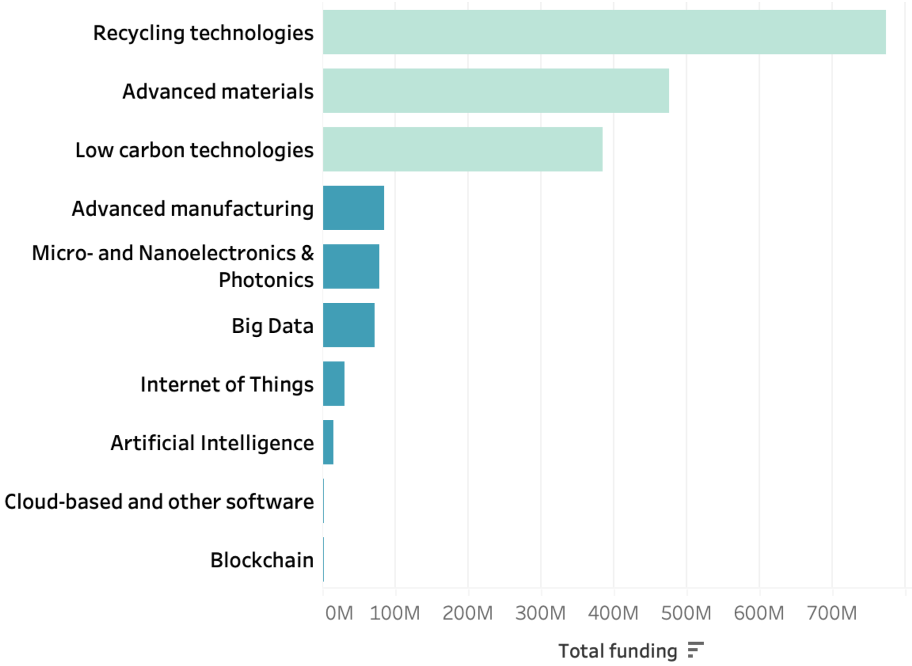
Regarding the investment directed towards startups developing new advanced materials, it has been fluctuating over the years, reaching a total of €607 m in 2022.

Moreover, access to funding for low carbon technologies has been increasing since 2015. For example, the German company C1 Green Chemicals[79] has developed an ultra-efficient catalysis process to mass-produce green methanol. Founded in 2022, it has already gone through three rounds of funding capturing €13 m.

As regards digital technologies, companies developing advanced manufacturing techniques and micro- and nanoelectronics and photonics have been the most successful among investors, however collectively not gathering as much interest as the green transition technologies with less than €100 m each over the indicated time period.

[77] Exit rounds refer to Initial Public Offerings (IPO), Post IPO equity, Post IPO debt and Post Ipo Secondary
[78] http://www.ioniqa.com/
[79] http://carbon.one

Figure 31: Total funding by type of technology in chemical companies since 2010

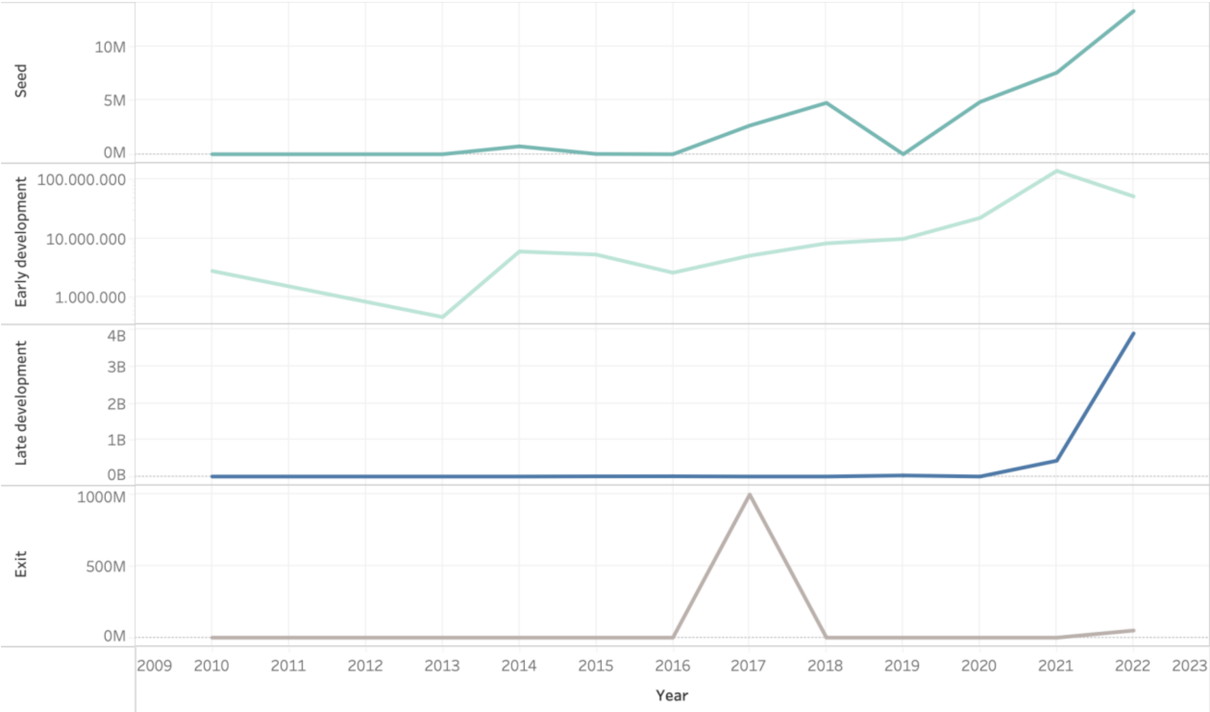


Source: Technopolis Group calculations based on Crunchbase and Net Zero Insights, 2023

Steel industry

Zooming in on the steel industry, startups developing digital and green solutions have received a total of €5.72 bn since 2010. As depicted in Figure 32 , seed-stage has been fluctuating but increasing since 2017, with a drop in 2019 and average annual growth of 126% between 2017 and 2022. Access to early venture capital has strongly increased after 2017, achieving €145 m in 2021. On the other hand, access to late-stage venture capital has been limited, with only 12 rounds taking place between 2015 and 2022. Similarly, only two exit operations are registered, namely two post IPO operations in 2017 and 2022.

Figure 32: Annual funding in Steel tech companies since 2010

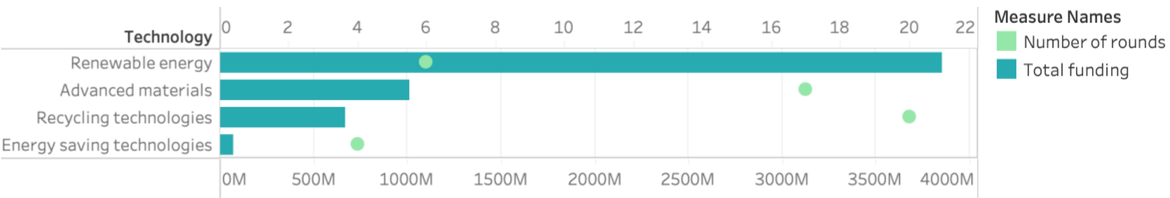


Source: Technopolis Group calculations based on Crunchbase and Net0 Insights

At the level of technologies, the green transition is dominated by investments in renewable energy technologies, followed by advanced materials and recycling technologies, as depicted in Figure 33. Green startups have gathered the majority of the funding, reaching a total of €5.75 bn.

69% of the funding was raised by the Swedish startup H2 Green Steel[80], hence the renewable energy technology group appears as the most funded technology. H2 Green Steel's technology is based on the use of renewable energy sources, such as wind and hydro power, to produce green hydrogen, which is then used as a reducing agent in their steelmaking process.

Figure 33: Total funding by type of technology for the green transition in steel companies since 2010



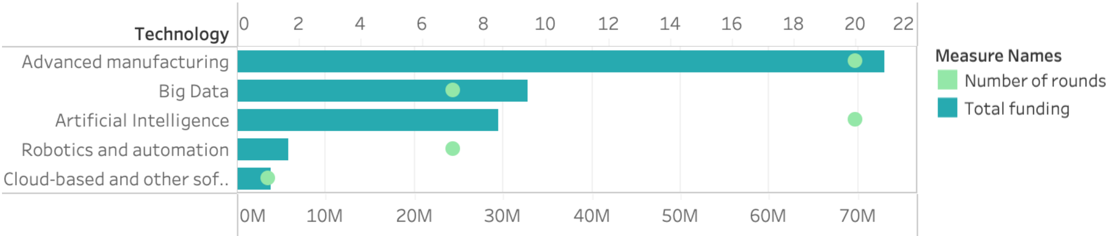
Source: Technopolis Group calculations based on Crunchbase and Net0 Insights

80 https://www.h2greensteel.com

Companies focused on developing advanced materials are the second most funded technology group, having reached a total of €1.01 bn since 2017[81].

Startups developing recycling technologies are also receiving important amounts of funding, having raised a total of €666 m in 42 funding rounds, with investments towards this type of startups having positively increased since 2017. An example is the Finnish startup Magstord[82], specialised in slag metal processing, that raised a total of €152 m in two funding rounds.

Figure 34: Total funding by type of technology for the digital transition in steel companies since 2010



Source: Technopolis Group calculations based on Crunchbase and Net0 Insights

Zooming in on the digital technologies, as depicted in Figure 34, a total of €124 m has been invested, with a sharp increase since 2018. Investment directed towards companies developing advanced manufacturing technologies has been fluctuating but overall increasing, reaching a total of €78 m for the considered period (2010-2022). Most of this funding was raised by companies focused on 3D printing, indicating a consistent interest of investors in these technologies.

A total of 15 companies developing AI powered solutions were involved in 32 seed and early-stage funding rounds since 2017, reaching a total of €29 m.

4.3 Foreign direct investment

fDi intelligence[83] tracks cross-border greenfield investment both intra EU, extra EU and globally, covering the EII industrial ecosystem among other industries. It provides real-time monitoring of investment projects, capital investment, and job creation with powerful tools to track and profile companies that are active investors in the field. The data source tracks projects that are expected to create new jobs and do not cover merges and acquisitions (already part of the VC data analysis above).

Figure 35 presents the total capital investment over time of foreign direct investment (FDI) energy intensive industry projects (from EU or to EU), excluding the oil and gas industries. Three categories of movement are visible: intra EU (FDI projects from EU27 countries to EU27 countries), foreign direct investment from non-EU countries into the EU27, and outwards EU27 FDI from EU27 countries.

Outward EU27 investments from EU27 countries are considerably higher than the intra EU and foreign direct investment into the EU27 over the observed period from 2010 to 2022 with a declining trend over the observed period. Inward investment in EU27 shows a slight increase over the overall period, while intra EU27 remains stable.

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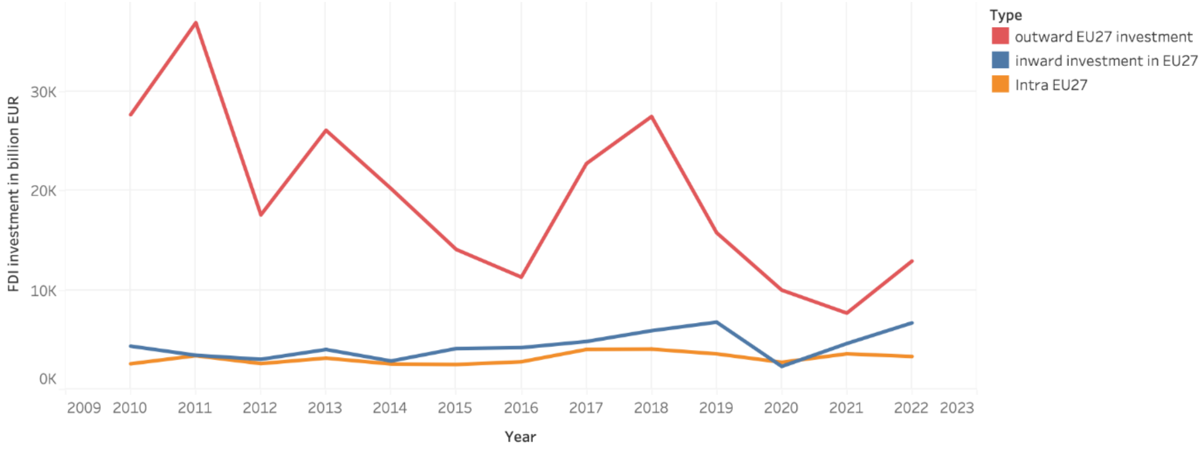
[81] 99% of this funding belongs to a Post IPO operation carried in 2017 by the supplier of high-tech polymer materials Covestro (https://www.covestro.com/)

[82] https://www.magsort.fi

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

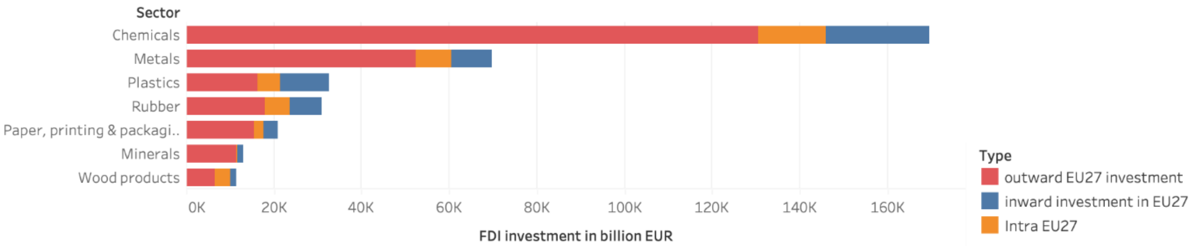
Figure 35: Foreign direct investment in the EII ecosystem from 2010 to 2022



Source: Technopolis Group calculations based on fdiInsights

Figure 36 depicts the sectoral breakdown for EII, showcasing the highest volume of investment across the three types, outward, inward and intra EU27 investment. The chemicals industry clearly shows the highest levels of investments, followed by metals, including steel.

Figure 36: Foreign direct investment in the EII industrial ecosystem from 2010 to 2022 sectoral breakdown



Source: Technopolis Group calculations based on fdiInsights

There have been 149 FDI projects associated to a recycling activity since 2010, reaching a total volume of €6015 bn (2% of the total), and with an average yearly growth of 137% since 2017. Zooming in, 55% of these investments are linked to the plastics industry, 23% to the metals industry and 11.4% to chemicals. For example, in December 2022, the Denmark-based plastics recycling company Letbek opened a 24,500 sq m warehouse in Sgro Logistics Park Poznan in Kmorniki, Poland. The space is expected to come into use in the second quarter of 2023.

Another example comes from the Germany-based copper producer Aurubis, which invested €77.40 m to build a bleed treatment facility at its existing production site in Olen, Belgium. The facility aims to recover valuable metals such as nickel and copper from electrolyte streams generated during metal production in electrolysis.

5. Skills

Key findings

The lack of skills and education is recognised as an important bottleneck to realise the full potential of new technological solutions within and across companies in the energy intensive industries ecosystem.

18% of the professionals working in the EII ecosystem claimed having at least one type of moderate digital skills and 4% having digital skills in areas such as Internet of Things, cloud, AI, big data, cybersecurity, robotics, blockchain, augmented and virtual reality. In addition, 6.2% of the professionals employed in energy intensive industries have skills relevant for the green transition.

Skills demand in the EII ecosystem was analysed based on the skills intelligence insights of Cedefop. **There were 1 136 403 unique job advertisements from companies between 2019-2022 in the EU27 specially related to the energy intensive industries ecosystem**. Among the supply of professionals with specific green skills within the EII ecosystem, the more sought after advanced green skills are: **application of transport industry management concepts in order to improve transportation processes, reduce waste, increase efficiency, and improve schedule preparation; science of biology; and energy efficiency.**

The top digital skills that appeared most often in EII job advertisement include advanced digital skills are **technical drawings and classification of databases (their purpose, characteristics, terminology, models and use such as XML databases, document-oriented databases and full text databases, next to monitoring and operating computer numerical controlled machines.**

Some industries of the EII industrial ecosystem are characterised by an older workforce with a lower level of education. They suffer from a lack of interest among young people although the demand for skilled people is growing, due to digitalisation and changes in data analysis, robotics, resource efficiency, recycling, business processes and overall transition, both in products and processes of the EII ecosystem.[84] In addition, the deployment of low-carbon technologies, necessary for the green transition, requires a well-designed transfer of existing skills while adapting to new skills. Continuous education and training, addressing recruitment difficulties and talent management, are hence essential.

The **18th large-scale skills partnership on EII** under the **Pact for Skills**, a flagship initiative under the European Skills Agenda, was set up in May 2023.[85] The partnership underpins the objectives set out in the recently presented Net-Zero Industry Act[86], following up on the Green Deal Industrial Plan and the European Year of Skills[87]. It also

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[84] European Commission, Directorate-General for Research and Innovation, ERA industrial technology roadmap for low-carbon technologies in energy-intensive industries – , Publications Office of the European Union, 2022, https://data.europa.eu/doi/10.2777/92567

[85] https://energy.ec.europa.eu/news/commission-launches-large-scale-skills-partnership-energy-intensive-industries-2023-05-10_en

[86] COM(2023) 161 - Proposal for a regulation of the European Parliament and of the Council on establishing a framework of measures for strengthening Europe’s net-zero technology products manufacturing ecosystem (Net Zero Industry Act)

[87] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-year-skills-2023_en

contributes to the EU headline target that by 2030, at least 60% of all adults should participate in training every year.

Other initiatives have been taken to drive up and reskilling at the level of the individual industries. The European Steel Technology Platform (ESTEP)[88] set up the **European Steel Skills Agenda (ESSA)** to lay out the approaches necessary to sustain a competitive industry. It was argued that, according to people employed in the sector, compared to technical skills, digital skills (e.g., advanced data analysis and mathematical skills, programming, cybersecurity) and green skills (e.g., waste reduction and management, water conversation) will experience a stronger increase in importance.[89] Nevertheless, there are differences in required levels of skills depending on job profiles, with metallurgical managers, supervisors and engineers needing the highest levels of skills.[90]

This section aims at analysing trends in the supply and demand of skilled professionals relevant for the green and digital transition based on experimental data from LinkedIn and from Cedefop. These data sources allow to gain insights into the development of digital and green skills in particular with the EII system given the lack of other similar data. LinkedIn enables to identify trends in the development and supply of skilled professionals in advanced technologies related to both digital and green transition. To harvest the data from LinkedIn, keywords capturing skills in each advanced technology category were defined and validated by industry and technology experts. They were subsequently used to construct queries for searching the database. Cedefop Skills intelligence provides insights into jobs and skills requested in online job advertisements by its dataset 'Skills in online job advertisement'. This dataset currently covers the EU27 countries (plus UK) and was developed based on the collection and analysis of more than 100 million online job ads from July 2018 onwards.

5.1 Green and digital skills in the energy intensive industries industry

The market supply of labour is the number of workers/professionals of a particular type and skill level who are willing to supply their labour to companies. LinkedIn data can measure this supply by providing insights about the number of professionals on the market with green and digital technological skills relevant to the energy intensive industries industrial ecosystem (Figure 37). Data have to be interpreted in the light of the use of LinkedIn within people employed in the energy intensive industries and country differences in representativeness need to be taken into account.

In order to capture the number of professionals working in the sector, occupations related to the industrial ecosystem have been taken into account. For the skills analysis of energy intensive industries, the following LinkedIn tags have been used: *Chemicals, Glass, Ceramics & Concrete, Plastics, Mining & Metals, Paper & Forest Products.*.

Green transition related skills follow the definition of Cedefop and mean "*the knowledge, abilities, values and attitudes needed to live in, develop and support a sustainable and resource-efficient society*" (Cedefop, 2012). In this study, 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

[88] https://www.estep.eu/

[89] ESSA Deliverable D3.2 Company Skills Requirements and Foresight. https://www.estep.eu/essa/download-area/deliverables

[90] ESSA Deliverable D3.2 Company Skills Requirements and Foresight. https://www.estep.eu/essa/download-area/deliverables

technologies and business models related skills (the list of keywords that have been used and are possible to track with the algorithm of LinkedIn is included in Appendix B).

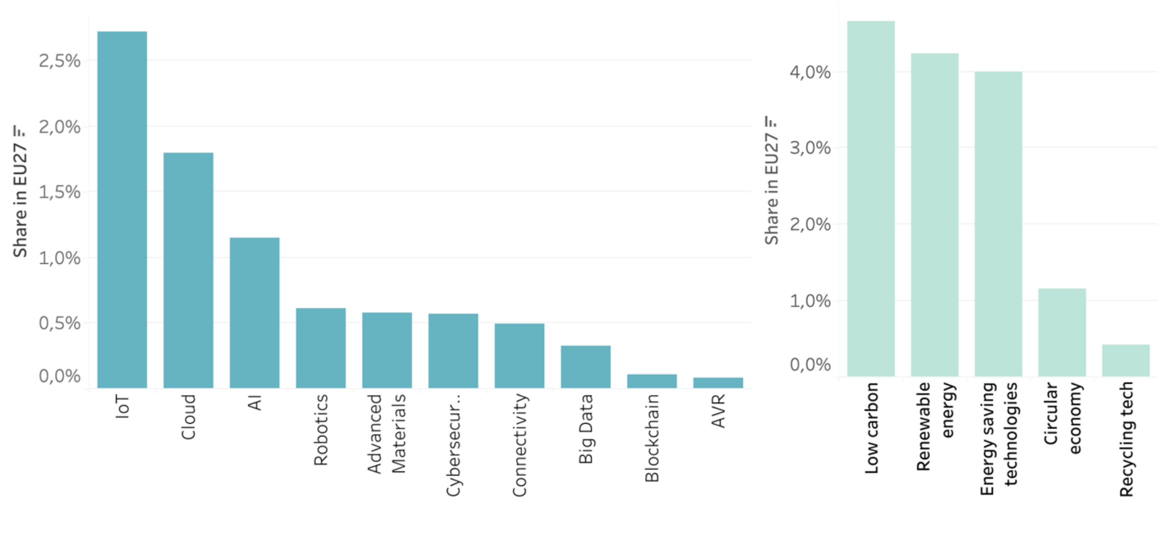
Moderate digital skills include the monitoring of basic and other digital skills. Cedefop distinguishes "*five types of skills under the digital skills umbrella such as information processing (e.g. using a search engine and storing information and data); communication (including teleconferencing and application sharing); content creation (such as producing text and tables, and multimedia content); security (e.g. using a password and encrypting files); and, problem solving (e.g. finding IT assistance and using software tools to solve problems)"*. (The list of keywords that have been used and are possible to track with the algorithm of LinkedIn is included in Appendix B).

Advanced digital skills have been defined as a specific group of digital skills in the context of the main digital technologies captured in this project notably in artificial intelligence, cloud computing, connectivity, robotics, Internet of Things, augmented and virtual reality and blockchain (the list of keywords that have been used and are possible to track with the algorithm of LinkedIn is included in Appendix B). LinkedIn data have to be interpreted in the light of its representativeness for EII and across the EU. An analysis of representativeness is provided in Appendix B and in the related methodological report.

The results of the analysis suggest that within the registered professionals on LinkedIn employed in the EII ecosystem, **18% claimed having at least one type of moderate digital skills and 4% having advanced digital skills in areas such as Internet of Things, cloud, AI, big data, cybersecurity, robotics, blockchain, augmented and virtual reality**.

In addition, **6.1% of the professionals employed in energy intensive industries have skills relevant for the green transition**. Low carbon, renewable energy and energy saving technologies notably lead the skills related to the green transition in this regard. Figure 37 provides further insights regarding skills at the level of specific advanced technologies.

Figure 37: Share of professionals employed in energy intensive industries with green and advanced digital skills and with a profile on LinkedIn



Source: Technopolis Group calculations, 2023

5.2 Skills demand

Skills demand in the EII ecosystem has been analysed following the skills intelligence insights of Cedefop, the European Centre for the Development of Vocational Training[91]. This dataset covers 28 European countries and is based on the collection and analysis of more than 530 online job advertisement sources (424 distinct websites) which are open-access sites. The dataset provides information on most requested occupations and skills across European countries based on established international classifications, e.g., ISCO-08 for occupations, ESCO for skills, and NACE rev. 2 for sectors.

Specific to the energy intensive industries ecosystem, **there were 1 136 403 unique job advertisements from companies between 2019-2022 in the EU27**. These job advertisements have been text-mined and the required skills analysed from the perspective of the green and digital transitions. The green pre-defined skills are from ESCO v1.1 and the digital are predefined from ESCO v1.1.1 which is currently being updated.

The European multilingual classification of Skills, Competences, Qualifications and Occupations (ESCO) is used as follows:

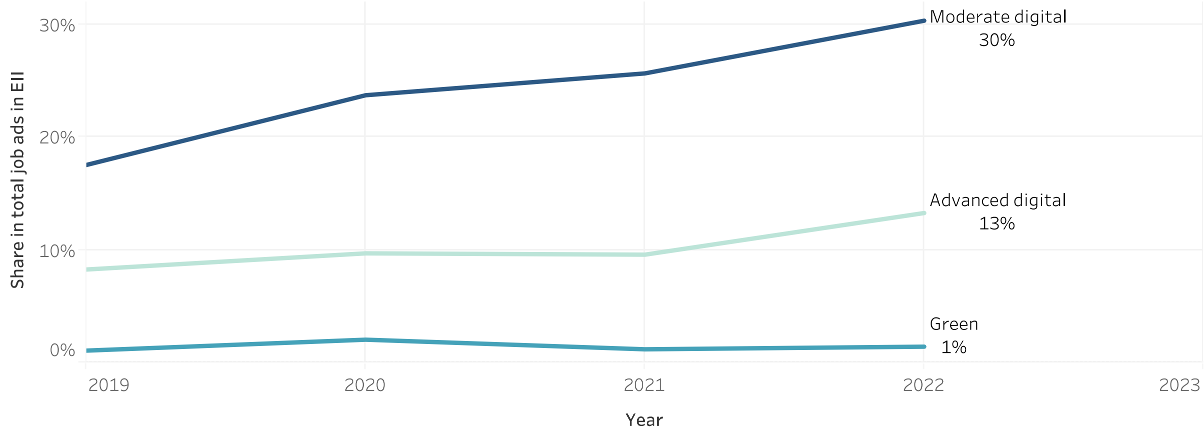
- **Green skills** (ESCO v1.1.) are those knowledge and skills which reduce the negative impact of human activity on the environment and were captured in line with the definitions of Cedefop (keywords presented in Appendix B).
- **Moderate and Advanced Digital skills** (ESCO v1.1.1 which is currently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

Online job advertisements that can be related to moderate digital technologies amount to 281 678 over the period from 2019-2022, and to green transition related skills amount to 15 917.

The share of online job advertisements that required any form of **moderate digital skills (excluding basic IT office skills) was 24.79%** over the period from 2019-2022 (and grew to 30% in 2022), while this percentage was **10.43% for advanced digital skills** (grew to 13% in 2022). Requirements related to the **green transition** appear less often on the advertisements notably in **1.4%** of the cases.

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

Figure 38: Share of online job advertisements that demand digital and green transition related skills within the total number of job advertisements in the EII ecosystem



Source: Technopolis Group calculations based on Cedefop data, 2023

The more sought-after digital skills include the following:

- Development of animations,
- Technical drawings,
- Classification of databases (their purpose, characteristics, terminology, models and use such as XML databases, document-oriented databases and full text databases),
- Monitor and operate a computer numerical controlled (CNC) laser cutting machine according to regulation,
- Monitor and operate a computer numerical controlled (CNC) metal punch press according to regulations.

The more sought-after green skills are:

- Reduction of waste, increase efficiency,
- Energy efficiency,
- Corporate social responsibility in terms of responsibility towards environmental and social stakeholders.

6. Sustainable competitiveness: the green performance of the ecosystem

Key findings

Energy intensive industries impact the environment in various ways, notably by generating air emissions, land contamination, noise pollution, waste, and other greenhouse gas (GHG) emissions. In this report, the environmental impact of industrial ecosystems has been analysed based on Exiobase data.

The results suggest that **the most relevant environmental challenges of the EII ecosystem are related to greenhouse gas emissions and material extraction, where the EII has an increasing negative impact** even if with some fluctuations. Land consumption has been relatively high.

In terms of greenhouse gas emissions of CO2, the EII industrial ecosystem's outputs are largely above the industrial average for the most part originating from the manufacturing of coke and refined petroleum products and manufacturing of plastic and rubber.

Material extraction is the second most challenging environmental pressure of the ecosystem. The main industry contributing to this indicator is the manufacturing of plastic and rubber.

In terms of land use, the EII industrial ecosystem lies above the global average, increasing over time and currently contributing with 8%. The manufacturing of wood and of products of wood and cork, are a leading contributor to this indicator, followed by the manufacturing of articles of straw and plaiting materials.

EII has been responsible for 7% of the total water consumption of all industrial ecosystems as the analysis of Exiobase data suggests, which is largely driven by the chemicals industry, however rubber and plastics also play a key role.

There are differences in the environmental impact of EII sectors. For instance, steel production is one of the most energy-consuming and CO_2 emitting industrial activities in the world. The mining of iron ore is incredibly energy intensive, causes air pollution in the form of, amongst others, nitrous oxide, carbon dioxide and monoxide, as well as water pollution. Steel production also requires large inputs of coke, for use in ovens generating air pollution and toxic wastewater.[92]

Given its impact on the environment, the EII is subject to many regulations at both national and European level. At EU-level, several environmental regulations that are critical include: the *Extractive Waste Directive*[93], *Waste Framework Directive*[94], *Industrial Emissions Directive*[95] and *Environmental Impact Assessment Directive*[96], and EIIs need permits at national, regional or local level before starting operations.[97] At the same time, most sectors in the EII ecosystem have been subject to carbon pricing through the **EU Emissions**

[92] https://www.theworldcounts.com/challenges/planet-earth/mining/environmental-impact-of-steel-production
[93] Directive 2006/21/EC. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32006L0021
[94] Directive 2008/98/EC. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02008L0098-20180705
[95] Directive 2010/75/EU. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32010L0075
[96] Directive 2014/52/EU. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0052
[97] SWD(2021) 277 final. For a resilient, innovative, sustainable and digital energy-intensive industries ecosystem: Scenarios for a transition pathway. https://ec.europa.eu/docsroom/documents/47059/attachments/1/translations/en/renditions/native

Trading System (ETS) since 2005.[98] These regulations are thus crucial in defining the operating environment for EIIs.

Several sources can be consulted to capture distinct elements of the environmental impact of the EII industrial ecosystem. This report draws upon data from Exiobase with the aim to measure trends in the environmental impact of industrial ecosystems (Exiobase 3.8[99]). Exiobase is a legitimate source of information referred to for example by the European Environmental Agency[100], the EC/JRC community[101], Eurostat[102], and by the European Commission to propose the regulation on carbon border adjustment mechanisms[103]. Pressure to environments refer to trade-embodied resources utilisation, and trade-embodied impacts.

Resource utilisation has been captured with five main dimensions which are considered in cross-industry comparisons. These dimensions are namely, **air emissions (incl. GHG), embodied land use, water consumption, material consumption and damage to the ecosystem.**

Figure 39 shows the summary of green performance indicators at EU level and its change from 2010 to 2021. Overall, the analysis suggests that the **most relevant environmental challenges of the EII ecosystem are related to greenhouse gas emissions and material extraction**. In terms of greenhouse gas emissions of CO_2, the EII industrial ecosystem's outputs are largely above the industrial average for the most part originating from the manufacturing of coke and refined petroleum products and manufacturing of plastic and rubber. **EII contributes to 14% of the total GHG emissions of all industrial ecosystems.** Comparing the emissions of the last ten years, overall emission levels stayed stable, also decreased for some time but then started to increase again after 2020.

Material extraction is the second most challenging environmental pressure of the ecosystem. The main industry contributing to this indicator is the manufacturing of plastic and rubber. It increased slightly its contribution in the ecosystem from 25% to 27% in the observed period. The manufacturing of other non-metallic mineral products also plays a clear role, however with a decreasing contribution over the observed period.

In terms of **land use**, the EII industrial ecosystem lies above the global average, increasing over time and currently contributing with 8%. The manufacturing of wood and of products of wood and cork, are a leading contributor to this indicator, followed by the manufacturing of articles of straw and plaiting materials.

EII **has been responsible for 7% of the total water consumption of all industrial ecosystems** as the analysis of Exiobase data suggests, which is largely driven by the chemicals industry, however rubber and plastics also play a key role.

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[98] The EU Emissions Trading System (ETS) works on the principle of 'cap-and-trade'. It sets an absolute limit or cap' on the total amount of certain greenhouse gases that can be emitted each year by the entities covered by the system. This cap is reduced over time so that total emissions fall. Under the EU ETS, regulated entities buy or receive emissions allowances, which they can trade with one another as needed. At the end of each year, regulated entities must surrender enough allowances to cover all of their emissions. https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3542

[99] Exiobase is a time series of environmentally extended multi-regional input-output (EE MRIO) tables. EXIOBASE 3 (3.8.2) [Data set

[100] EEA 2022. Visit 12/10/2022. https://www.eea.europa.eu/data-and-maps/data/external/exiobase

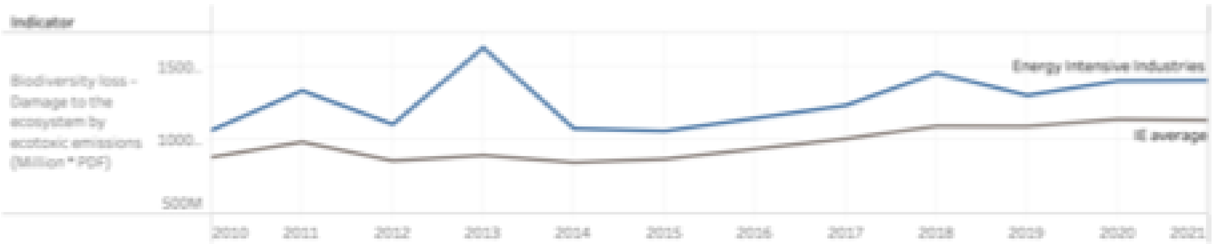
[101] Beylot, A., Secchi, M., Cerutti, A., Merciai, S., Schmidt, J. and Sala, S., 2019. Assessing the environmental impacts of EU consumption at macro-scale. Journal of cleaner production, 216, pp.382-393. https://doi.org/10.1016/j.jclepro.2019.01.134

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

[103] EC (2021) REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL. Establishing a carbon border adjustment mechanism. COM(2021) 564 final.

In this study, biodiversity loss was captured by data on ecotoxic emissions. This indicator shows that the **EII industrial ecosystem increasingly contributed to damaging the natural ecosystem over the past years, and always above the IE average,** which is mainly attributed to the manufacturing of basic metals.

Figure 39: Indicators to capture the green transition of the EII industrial ecosystem, Exiobase, 2023



Source: Technopolis Group, 2022, based on Exiobase data

Within the EII ecosystem several sub-industries drive the environmental impacts. The data suggest that manufacturing of rubber and plastic products were the major contributors to **material extraction and blue water consumption in 2020**. These results align with other studies' findings that in 2015, seven EU countries' rubber and plastic manufacturing were major contributors to environmental damage per unit of production value[104].

The manufacturing of coke and refined petroleum products are the industries driving most of the local (**particulate matter**) and global emissions (**GHG**) in the EII. Investigations of OECD countries, indicate that although the industry has gone through substantial technological progress in for emissions mitigation, the scale of consumption surpassed all the efficiency gains; in other words, in this industry, **the scale of consumption is outpacing the efficiency gains**[105].

The **manufacture of basic metals is the key driver of the IE's damage to ecosystem**. Life cycle assessment (LCA) with material flow analysis studies indicate that processing of rare earth and basic metals, zirconium, and so on, have an ecotoxicity effect on earth that leads to biodiversity loss. While EU manufacturing of basic metals may opt to externalise various life cycle stages of the extraction and processing to non-EU countries, damage to the ecosystem continues to increase because the scale of consumption remains high. Moreover, there are **efficiency losses** by outsourcing to less technologically advanced industries in non-EU countries, which leads to an **increase of damage to the ecosystems embodied in traded** for consumption in the EU.[106].

The **manufacture of wood and of products of wood and cork is the key driver of the land use** of the EII. An investigation of the EU consumption intensities showed a steady increase for forestry and furniture related products since the year 2010, being the main contributor in the EU bioeconomy related activities. On the other hand, unlike other environmental impact areas, land use consumption intensity is still within the planetary boundaries or within the earth's reproduction capacity[107].

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[104] The seven EU countries included Austria, Belgium, Germany, Denmark, France, Netherlands, and United Kingdom. See Brink, C., Drissen, E., Vollebergh, H., & Wilting, H. (2020). Accounting for Environmental Damage by Material Production and Use: A Comparison of Seven Western European Countries. (PBL Publication; Vol. 3512). Planbureau voor de Leefomgeving.

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IPOL Energy-intensive industries- Challenges and opportunities in energy transition

Transition pathways for European industrial ecosystems (n.d). https://single-market-economy.ec.europa.eu/industry/transition-pathways_en

Appendix B: Methodological notes

Crunchbase and Net Zero Insights

For the chemical industry analysis

Crunchbase: Chemical, Chemical Engineering,

Net0: Chemical

For the steel/metal industry analysis:

Crunchbase: Industrial Manufacturing, Manufacturing, Industrial Engineering AND keywords (steel, metal, iron, gold, aluminium)

Net0: Steel, Metal and Metallurgy

Foreign direct investment

The following sectors are included in the foreign direct investment analysis.

Table 1: Industry tags included in the FDI analysis

Sector	Sub-sector
Plastics	Laminated plastics plates, sheets & shapes
	Plastic pipes, pipe fitting & unlaminated profile shapes
	Artificial & synthetic fibres
	Other plastics products
	Plastics packaging materials & unlaminated film & sheets
	Plastic bottles;
Chemicals	Basic chemicals
	Pesticide, fertilisers & other agricultural chemicals
	Soap, cleaning compounds, & toilet preparation
	Paints, coatings, additives & adhesives
	Other chemical products & preparation
	Resin & artificial synthetic fibres & filaments
Metals	Steel products; Iron & steel mills & ferroalloy
	Nonferrous metal production & processing
	Alumina & aluminium production and processing
	Architectural & structured metals
	Copper, nickel, lead, & zinc mining
Wood products	Wood products
Rubber	Tyres
	Rubber hoses & belting
	Other rubber products;
Paper, printing & packaging	Pulp, paper, & paperboard
Minerals	Nonmetallic mineral mining & quarrying
	Other non-metallic mineral products

Survey

Table 2: Survey sampling for the EII ecosystem

NACE code		Sample
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	228
C17	Manufacture of paper and paper products	210
C19	Manufacture of coke and refined petroleum products	95
C20	Manufacture of chemicals and chemical products	295
C22	Manufacture of rubber and plastic products	200
C23	Manufacture of other non-metallic mineral products	182
C24	Manufacture of basic metals	254

Source: Technopolis Group

Environmental certificates

ISO annual surveys report the number of companies/organisations with environmental certificates. Environmental certificates were the ISO 14000, which was updated requiring more stringent standards and practices in the year 2015. The new standard was then named ISO 14000/2015. Holders of the ISO 14000, starting from the year 2015, had to be re-certified to gain the new ISO14000/2015 certificate. New sustainability and environmental practices had to be put in place; with organisational change and financial requirements implied. Accreditation bodies had also to adopt new verification procedures, with their corresponding time lag. This may explain the drop in number of certified companies/organisations from 2015 to 2017.

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	LinkedIn categories used
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