Monitoring the green and digital transition of industrial ecosystems

Updated Methodological Report

2024/2025

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1. Introduction

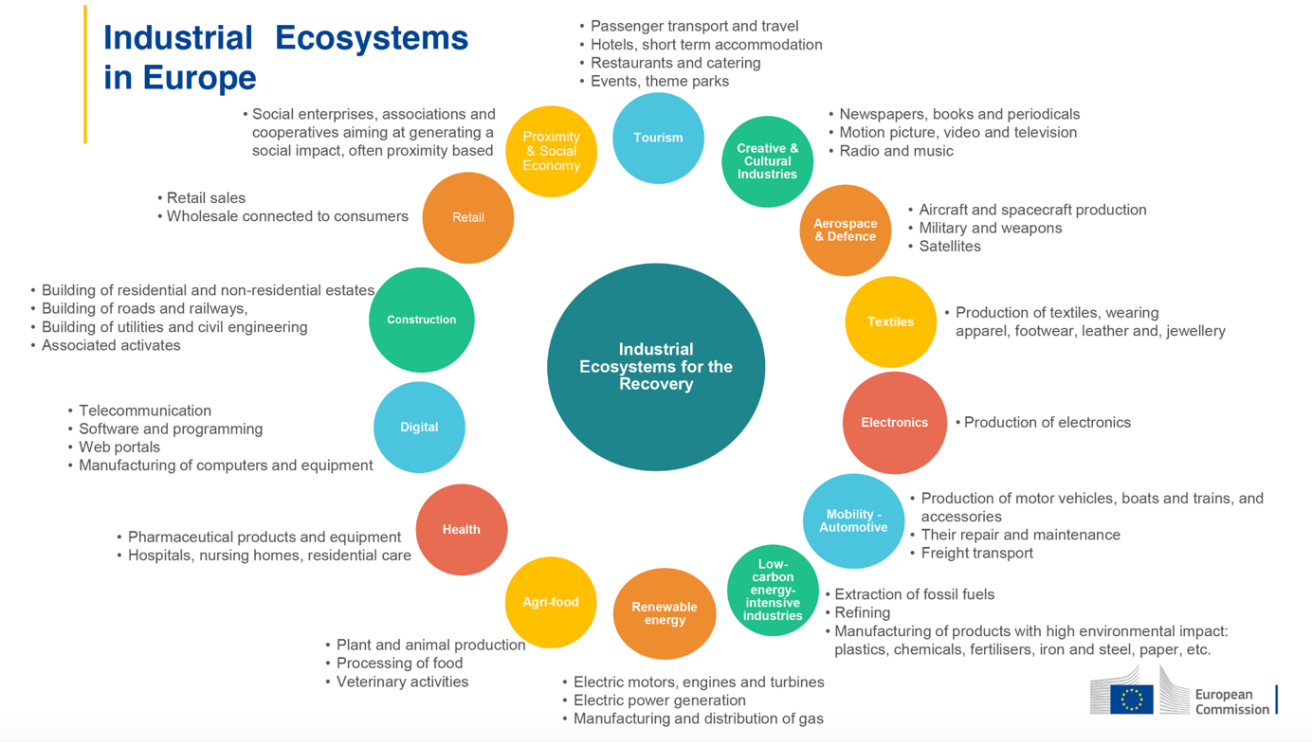
1.1. Objectives

This methodological 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). It presents the methodological and indicator framework underpinning the choice of indicators and data sources to be measured in this project.

The overall goal of the project is to **analyse the green and digital transformation of industrial ecosystems and report on the progress**.

The EU's updated industrial strategy from May 2021[1] has outlined **14 industrial ecosystems** including *aerospace and defence, agri-food, construction, cultural and creative industries, digital, electronics, energy intensive industries, energy-renewables, health, mobility – transport – automotive, proximity, social economy and civil security, retail, textile and tourism.* 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[2]. This project analyses the green and digital transition of 12 industrial ecosystems and tackles the performance for digital and energy-renewables ecosystems horizontally, meaning both ecosystems are being analysed in all industrial ecosystems reports.

Figure 1: 14 industrial ecosystems as highlighted in the European industrial strategy in 2020



Source: European Commission, 2020

[1] European Commission (2021). Communication on Updating the 2020 New Industrial Strategy, COM(2021)350 final https://commission.europa.eu/system/files/2021-05/communication-industrial-strategy-update-2020_en.pdf
[2] European Commission (2020). A New Industrial Strategy for Europe, COM/2020/102 final Commission Communication: A New Industrial Strategy for Europe | European Commission (europa.eu)

1.2. Selection of dimensions

The conceptual framework builds upon the measurement of twin transitions within industrial ecosystems. It draws from the literature on green transformation including the shift towards a low-carbon and circular economy, moreover on digital transformation and technological change, as well as from research on socio-techno-economic systems (e.g. Wieczorek et Hekkert, 2012; Geels, 2018; Long et Holmen, 2021).

Industrial systems are made up of different processes, each with a specific role that contributes to how well the system works and how it evolves over time. Hekkert and Wieczorek (2007 and 2012) have studied these roles and identified key functions that are especially useful for understanding and analysing such systems. Their work has been used as a foundation to select the most important functions for this project.

The Industrial Forum's 'Blueprint for the development of transition pathways[3]' has put forward seven building blocks that covers a key aspect of the twin transition and the move to greater resilience. In this conceptual framework, these building blocks have been adopted in line with available data and indicators and integrated into the structure of the analysis. Further differentiation has been made between functions related to firm dynamics and the state of the broader ecosystem. The EMI indicator framework contributes to the industrial transition pathways put forward by the European Commission and co-created by industrial stakeholders[4]. A transition pathway is a detailed and actionable plan designed to guide the transformation of industrial ecosystems. These pathways outline the steps needed to change business models and value chains to support a green, digital, and resilient European economy. The EMI project feeds these industrial pathways with quantitative analysis.

As a result of the review and in alignment with the methodology of the Advanced Technologies for Industry (ATI) project, **three key pillars and five dimensions** have been selected for the indicator framework. The measurements include 1) Industrial Efforts, encompassing technology adoption, technology generation and private investments; 2) Framework Conditions, skills and public investments; and 3) Impacts, focusing on sustainable competitiveness, environmental and digital performance.

Efforts

Technology generation: Knowledge creation on the supply side is essential for technology producers to develop new technologies, which are embodied in new or improved products and services. It also enables them to improve and adapt their products after market introduction to meet the needs and characteristics of targeted markets. Ultimately, this process creates value for the economy, environment, and society.

Technology adoption: Technology adoption refers to the extent to which green and digital technologies and related new and circular business models are integrated and utilised within the industrial ecosystem and the economy. This dimension assesses how effectively businesses embrace and implement these technologies and solutions to enhance environmental sustainability, productivity and competitiveness. Technology diffusion is understood as the process how technologies are shared and replicated by industrial stakeholders. Businesses adopt green and digital technologies in two main ways: they can use them in their operations, triggering a new wave of process innovations, or integrate them into new products, sparking a new cycle of product innovation (Surinach et al, 2009).

Private investments: The volume of financial resources dedicated to supporting the green and digital transition is crucial for assessing progress towards new developments. Firms invest in digital technologies, key enabling technologies, clean production, and green business models to become more competitive, achieve higher cost-effectiveness, and

[3] DocsRoom - European Commission (europa.eu)
[4] https://single-market-economy.ec.europa.eu/industry/transition-pathways_en

create better value for society. Funding for these digital and green transformation strategies can be obtained from shareholders, private equity, venture capital investors, bank loans, and dedicated public government programmes.

Framework Conditions

Public investments: Public investments supporting the green and digital transition are a key policy lever for addressing the challenges faced by industries undergoing transformation and for accelerating transition activities. According to the Draghi report on EU competitiveness[5], the required scale of investment to digitise and decarbonise the economy amounts to an increase in the investment to GDP ratio by five percentage points of EU GDP. The report points out that such level cannot be achieved through private funding only. Considering the fragmentation in public funding, a systematic monitoring within the EU is crucial for assessing the progress of industrial ecosystem transitions.

Skills: Human capital is essential for all activities within a technological system. It is crucial for technology developers who rely on skills and R&D investments to develop and improve technologies. New technologies create a demand for labour resources, both for technology production and due to ongoing modernisation. On the supply side, experienced personnel and the acquisition of necessary skills are vital for developing the absorptive capacity of technology recipients.

Impacts

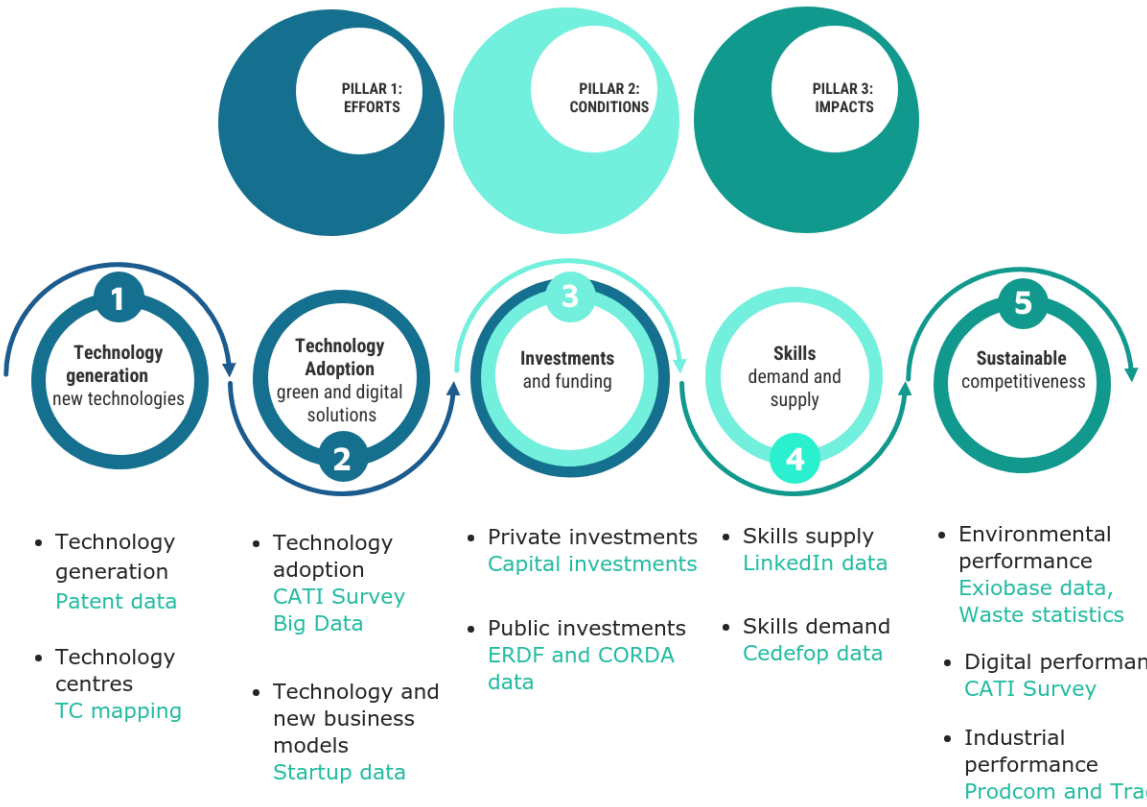
Environmental performance: As outlined in the Blueprint, each ecosystem needs to identify its core strengths, weaknesses, opportunities and threats, thus revealing areas for improvements and stimulate sustainable production, investments and quality job creation. This dimension captures green transition regarding the status of emissions, energy use and impact on the environment. It includes a reflection about the environmental footprint of each industrial ecosystem and the on-going trends and change over time.

Digital performance: Digitalisation is a driver of productivity and future growth across all industrial ecosystems and company sizes. Adopting digital technologies has been shown to affect company operations in multiple and heterogeneous ways. This dimension contributes to monitoring the impact of digitalisation over time and understanding how it affects each industrial ecosystem.

Industrial performance: Exposure to shocks and disruptions to the global trading system affect industrial ecosystems' performance and the EU's economic resilience and competitiveness. Production and trade are the two main components monitored in this study, with the objective of estimating the extent to which green and digital technologies have been integrated within industrial products.

[5] https://commission.europa.eu/topics/eu-competitiveness/draghi-report_en

Figure 2: Overview of monitoring industrial ecosystems and relevant data sources



Source: Technopolis Group, IDEA Consult and Fraunhofer ISI

1.3. Selection of technologies

The green and digital transformations are monitored through a set of technologies selected to ensure continuity with previous projects such as the Advanced Technologies for Industry and the Key Enabling Technology Observatory. These technologies were chosen following a review and expert opinions on the most transformative technologies relevant for industrial ecosystems. The list of technologies has been further complemented with non-technological business models, particularly services in the context of the circular economy. The list is presented in the Table below. The detailed technology definitions are included in Appendix A.

In addition, technological considerations specific to the industrial ecosystems are captured across the five dimensions of the EMI monitoring framework. In technology adoption using survey data AI and big data are measured separately in order to capture the adoption of advanced big data analytics tools, which are however not AI based. For instance, in textiles manufacturing, one can put in place a more complex system to analyse data from logistics, material sourcing, and inventory levels that can enhance transparency also linked to the digital product passport, but this is not yet AI.

In technology generation a distinction is made between industrial ecosystems which generate advanced technologies and those industrial ecosystems that primarily adopt them. For example, patent applications is discussed in the context of the manufacturing-based industrial ecosystems such as Agri-Food, Mobility, Transport and Automotive or Textiles.

Table 1: List of technologies and non-technological solutions monitored

Green Transition	Digital Transition
Advanced Materials	**Advanced Manufacturing and Robotics**
Biotechnology	**Artificial Intelligence**
Energy Saving Technologies	**Augmented and Virtual Reality**
Renewable Energy Technologies	**Big Data**
• **Solar Power**	**Cloud Technologies**
• **Wind Power**	**Digital Security/Cybersecurity**
• **Other (geothermal, hydropower, biomass)**	**Internet of Things**
Recycling Technologies	**Micro- and Nanoelectronics and Photonics**
Circular Business Models	**Quantum Computing**

Source: Technopolis Group, IDEA Consult and Fraunhofer ISI

2. Overview of the adapted indicator framework

The revision of the monitoring framework seeks to enhance the communication of results, interpretability, and relevance in the context of the industrial ecosystems' twin transition pathway. The goal is to offer a harmonised set of indicators that measure all industrial ecosystems with the same methodology complemented with a set of tailored (already available) indicators that are specific for each industrial ecosystem. The adapted indicator framework incorporates enhancements to retained indicators, broadens the spectrum of data sources, and introduces novel indicators.

The green and digital transformation of industrial ecosystems in particular at the level of individual technologies lacks data and existing indicators in general. This is the reason why the indicator framework includes novel data sources such as LinkedIn or Cohesio, where more suitable indicators could not be identified. These indicators need to be interpreted in light of what the data represent and the segment of reality that it captures more specifically. A detailed representativeness analysis has been included in Appendix E.

The adapted indicator framework is outlined as follows:

Table 2: Adapted indicator framework harmonised for the IE analysis

Dimension	Indicator	Source	Time series	Digital and Green Transition
Technology generation	Share of patent applications in digital and green technologies per industrial ecosystem	Patstat	2005-2022	Technology specific
Technology generation	Total Number of Trademarks Worldwide per Ecosystem as Reference	EUIPO	2010-2022	Technology specific
Technology generation	Technology startups and scaleups: Number of technology startups and scaleups generating technologies; share in total	Crunchbase Net Zero Insights	2010-2024	Technology specific
Uptake of green and digital	Share of companies adopting digital and green technologies	Survey	2023, 2024	Technology specific
Uptake of green and digital	Number of technology centres relevant for the digital and green transition of industrial ecosystems	TC Mapping	2023, 2024	no
Investment	Private equity and Venture Capital investment in the green and digital Transition: Value of private equity and VC funding raised in technologies per industrial ecosystem	Crunchbase Net Zero Insights	2015-2024	Technology specific
Investment	Investment costs in the green and digital transition	Survey and Orbis data combined	2023, 2024	Digital and Green
Investment	EU R&D funding in digital and green transitions per industrial ecosystem	CORDA	2014-2020 2021-2027	Digital Green
Investment	Cohesion policy budget allocated to green and digital transition (includes CF, ERDF, ESF, YEI)	Cohesio-DG REGIO data	2014-2020 2021-2027	Digital Green

Dimension	Indicator	Source	Time series	Digital and Green Transition
Skills	Share of professionals with digital and green transition skills employed in industrial ecosystems	LinkedIn	2019-2024	Technology specific
Skills	Share of job advertisements with requirements for digital and green transition skills per industrial ecosystem	Survey	2025	Technology specific
Sustainable competitiveness	Production global competitiveness: country share in global production of manufacturing goods	Prodcom	2008-2021	Non-tech specific
Sustainable competitiveness	Production country significance: Share of production in a green or digital technology over a country's total production of manufacturing goods	Prodcom	2008-2023	Digital Green
Sustainable competitiveness	Trade balance: difference between exports and imports in relation to the total trade volume (exports plus imports) of a country	Uncomtrade	2015-2023	Digital Green
Sustainable competitiveness	Emissions of greenhouse gases (as defined in IPCC AR5) converted to CO2 equivalents using the GWP100 conversion (Global Warming Potential for a 100-year time horizon) (megatons CO2)	Figaro	2010-2022	Green
Sustainable competitiveness	Greenhouse gases (CO2, N2O in CO2 equivalent, CH4 in CO2 equivalent, HFC in CO2 equivalent, PFC in CO2 equivalent, SF6 in CO2 equivalent, NF3 in CO2 equivalent)	Eurostat Air emissions accounts by NACE Rev. 2 activity	2014-2023	Green
Sustainable competitiveness	GHG emissions	Exiobase	2015-2023	Green
Sustainable competitiveness	Materials extraction (used & unused)	Exiobase	2015-2023	Green
Sustainable competitiveness	Land use	Exiobase	2015-2023	Green
Sustainable competitiveness	Water use	Exiobase	2015-2023	Green
Sustainable competitiveness	Biodiversity (damage to the ecosystem)	Exiobase	2015-2023	Green
Environmental impact	Environmental management: Number of organisations with registered environmental management system ISO 14001, EMAS and other	ISO	2010-2023	Green

Source: Consortium

3. Sources and methods

This chapter presents the methodological steps to collect data and calculate indicators per data source.

3.1. Technology adoption

3.1.1. EMI Enterprise Survey

Rationale: The business survey collects data on the level of progress towards the green and digital transition among European SMEs and large companies across the EU27, encompassing 12 industrial ecosystems. It also gathers information about related investments. A random sample of companies has been drawn, focusing on high-level decision-makers who can provide informed reflections on the adoption of advanced technologies within their organisations. The broad size of the survey sample was 6 011 respondents in 2024.

The interviews have been conducted via telephone, ensuring high quality and accuracy of responses with the help of computer-aided telephone interviewing (CATI) system. The survey was translated to and conducted in multiple languages aiming for the broadest geographical coverage possible (Italian, Spanish, German, French, Greek, Polish, Lithuanian, Portuguese, Bulgarian, Romanian, Hungarian).

The table below provides the samples per industrial ecosystem for the 2024 edition of the survey. These numbers are the result of a representativeness check using Eurostat data for the population and taking into account error margins to determine the reliability of the results. The final numbers are adjusted to the project's available resources and the actual sample size achieved.

Table 3: Sample size per ecosystem in 2024

Industrial ecosystem	#	Industrial ecosystem	#
Aerospace & Defence	63	Health	96
Agri-Food	706	Mobility - Transport - Automotive	625
Construction	624	Proximity, Social Economy and Civil Security	69
Cultural and Creative Industries	755	Retail	667
Electronics	647	Textile	578
Energy Intensive Industries	672	Tourism	605

Table 4: Targeted sample size per ecosystem in 2025

Industrial ecosystem	#	Industrial ecosystem	#
Aerospace & Defence	100	Health	180
Agri-food	480	Mobility - Transport - Automotive	300
Construction	630	Proximity, Social Economy and Civil Security	200
Cultural and Creative Industries	520	Retail	560
Electronics	150	Textile	210
Energy Intensive Industries	240	Tourism	540

Eligible respondents are decision makers with major responsibility in the field of digital transformation or environmental sustainability. Individuals best qualified to answer questions about the digital and green transformation strategy and related activities may include technical directors, technical managers, founders, owners, sustainability managers, ICT specialists, heads of digitalisation, heads of environment). In smaller enterprises, the respondent should be someone at the level of managing director or the owner. A screening question needs to be included at the very beginning to ensure that respondents with not an adequate profile are eliminated from the sample.

Table 5: Indicator table

Indicator	Timeline	Data source
Share of companies adopting green technologies	2023, 2024, 2025	EMI Survey
Share of companies adopting digital technologies	2023, 2024, 2025	EMI survey

Source: Technopolis Group

Data quality measures

To ensure the integrity of the survey data, several quality control measures are implemented, in particular we have specific measures in place for:

- Validating the survey questionnaires and responses to make sure they respond to the key research questions and are clearly understood
- Reliability, in terms of the right level of persons responding to the survey per company and consistency of responses
- Completeness notably making sure the responses are complete, accurate and free from errors or biases.

Representativeness

The EMI Enterprise surveys achieved an accuracy below 5.5% at a 95 percent level of confidence for the industrial ecosystems. The margin of error calculation uses a conservative estimate of p=50%, which assumes the maximum possible variability in responses.

3.1.2. Technology startups

Rationale:

Technology startups represent key building blocks in the transition towards a more digital, green and resilient economic model. Entrepreneurial activity helps accelerate the diffusion of technologies in industrial ecosystems and startups that provide green and digital solutions are relevant indicators of how the industrial ecosystem is transforming itself to reach environmental sustainability objectives. Therefore, we analyse tech startup creation as part of the technology generation dimension of this monitoring framework.

Methodology:

In this study, startups are defined as "*young, innovative, growth–oriented businesses in search of a sustainable and scalable business model"* (NESTA, 2015). The analysis focuses primarily on technology-based startups. More specifically, digital tech startups do not simply develop or adopt digital technologies but digital is an inherent part of their value proposition (Oestreicher-Singer and Zalmanson, 2012; Griva et al, 2023). Environmental startups are another form of young, innovative business that develop and implement products, technologies and services that contribute to environmental sustainability, for

example by reducing greenhouse gas emissions, improving energy efficiency, adopting a circular economy approach (see in Bergset et Klaus, 2015).

For the purposes of this analysis, startups have been defined as founded after 2015, however, in certain reports a longer time span is applied, and the evolution of tech companies established since 2010 are monitored.

With the objective to analysing tech startups and related venture capital investment two data sources are used notably Crunchbase[6] and Net Zero Insights[7].

Crunchbase is a widely trusted source of primary data on venture capital and private equity innovative companies. It is a provider of innovative, investment-backed technology active companies in the EU27 and competing economies such as the US. Crunchbase information includes investments and funding information, founding members and individuals in leadership positions, mergers and acquisitions, news, and industry trends. Originally built to track startups, the Crunchbase website contains information on public and private companies on a global scale. Net Zero Insights is a specialised database of over 19 000 European startups identified as green innovators. It provides information about the location, age, investments, climate change challenge objectives, circular business models of the companies included. Additionally, it covers the sustainable development goals addressed by each product/service offered by a company.

Figure 3: Overview of Crunchbase Information

Company information	Financing information
• **Company information risk financing information** • **Company size class** • **Location (country, city and region)** • **Primary role (firms, group, investor, university and other), status (operating, acquired, IPO or closed)** • **Founding date** • **Dates of the record** • **Industry Group. Classification in terms of main activities of the organisations)** • **Industry. Sub-classification in terms of activities of the organisations** • **Social media information** • **Contact (company and staff e-mail)**	• Amount of capital involved • Type of round • Number of rounds • Number of investors involved • Investment stage (e.g. VC, business angel, private equity) • Profit/revenue information for 4 last years

Source: Technopolis Group

As introduced above, Crunchbase and Net Zero Insights classify their data through a tagging taxonomy that includes industry tags as well as tags related to technologies (AI, Blockchain, etc). Appendix C provides an overview of the matching that has been done between the studied industrial ecosystems and the tags available in Crunchbase and Net Zero Insights, in collaboration with the experts of each industrial ecosystem. To overcome the limitations of the tagging taxonomy, and in order to capture all industrial segments of each ecosystem, the project team also used keywords to further scrape relevant companies.

For the Crunchbase data, the data collection was done through their API, which enabled quicker extractions and more sophisticated text mining of data. In the case of Net Zero

[6] https://www.crunchbase.com/
[7] https://netzeroinsights.com/

Insights database, an additional scraping exercise was done to cover those industrial ecosystems that are currently not present in their sectoral classification.

Based on the pre-selected tags and keywords, our team collected startups founded during the period between 2010 until 2022 to allow for an analysis over time.

To further indicate the type of digital and green technology being developed, we run a text-mining exercise in which we classified the collected data according to a pre-defined technological taxonomy tailored to the industrial ecosystem.

Table 6: Indicator table

Indicator	Timeline	Data source
Number of technology startups and scaleups generating technologies; share in total	2015-2024	Crunchbase NetZero Insights
Number of startups per IE per country	2015-2024	Crunchbase NetZero Insights

Source: Technopolis Group

3.1.3. Big data analysis and text mining of company websites

The indicator framework has been further strengthened by leveraging data/text mining and natural language processing to help improve the understanding on the transition towards green and digital including the uptake of technologies and the generation of related products and processes. This analysis has been performed in a selection of industrial ecosystems namely Agri-Food, Culture and Creative Industries, Proximity and Social Economy, Textiles, Tourism.

The methodological approach of the analysis is supported by models that utilise scientific and industry data corpuses specific to the industrial ecosystems. These models are designed to provide detailed insights into the scope of the green and digital transition pillars.

The models generate a list of High Priority Clusters (HPCs) that frame the green and digital transition pillars using key terms. This approach enables a high level of granularity in the analysis, allowing for a more precise understanding and interpretation of the activities undertaken by companies in each industrial ecosystem.

By utilising HPCs and their corresponding key terms, the analysis can set minimum thresholds for the presence and frequency of these terms within HPCs. These thresholds serve as qualifying criteria for companies, determining their inclusion within the Green and Digital transition pillars. The team conducting the analysis can adjust the level of stringency by setting specific thresholds for key terms, ensuring that companies meeting the criteria are considered in the analysis.

Overall, the use of models based on scientific and industry data corpuses, combined with the identification of HPCs and key terms, provides a robust and systematic approach to analyse the green and digital transition pillars within industrial ecosystems.

3.2. Investments and funding

3.2.1. Private investments

3.2.1.1. Venture capital and private equity

Rationale: Primary data on venture capital and private equity investment in innovative startups and firms have been sourced from the Crunchbase and Net Zero Insights databases. Venture capital provides financial resources to businesses aiming to accelerate the development and scaling of green and digital technologies. It also fosters an entrepreneurial ecosystem that supports sustainable and digital transformation, making it a vital indicator for monitoring the seeds of change.

In this project, startups are defined as young companies founded in 2017 or later (with an operational history of seven years or less).

Methodology: Data on funding rounds have been collected across all industrial ecosystems based on Crunchbase and Net Zero Insights. Building on a text mining exercise performed to classify startups per industry and technology, the investment stages have been tagged. Based on the keywords indicated in Appendix C, funding rounds were investigated dated after 2010 for any company (regardless of the founding date) that fosters and provides a solution for the green or the digital transition within the specific industrial ecosystem. Venture Capital funding is typically divided into stages, commonly referred to as Series A, B, C, etc., representing different levels of investment as a company grows that are indicated below. The following investment stages were taken into account:

- Seed. This stage includes all funding instruments that occur in the early phase of development of startups. Types of funding under this stage include the following: Pre-Seed, Seed, Angel, Accelerator/incubator, Product Crowdfunding, Equity Crowdfunding, Crowdfunding, Award/Prize
- Early Development. Here early Venture Capital investment rounds have been included (up to €20 m), Convertible Note, Series A[8], Corporate and Private Equity (up to €20 m)
- Late Development. Operations within this stage include advanced VC rounds (>€20 m), starting from Series B[9].
- Exit. Here operations have been included for established startups, including corporate shares to the general public, acquisitions and merger operations.

Figure 4: Summary of investment stages and instruments

Stage	Type of funding instrument
Seed	Pre-Seed
	Seed
	Angel
	Initial Coin Offering
	Grant
	Crowdfunding

[8] Series A is used to scale a proven product or service. This stage often focuses on market penetration, acquiring new customers, and refining the business model.

[9] Series B refers to expansion stage funding to build on proven success. This includes scaling operations, entering new markets, and hiring talent. Series C refers to accelerating growth to prepare for significant expansion, acquisitions, or entering international markets. Series D is for companies that need further capital for scaling, restructuring, or preparing for an IPO (Initial Public Offering).

Stage	Type of funding instrument
	Accelerator/incubator
Early development	Convertible Note
	Corporate Round
	Series A
	Early VC (up to €20 million)
	Equity round (up to €20 million)
Late development	Series B
	Series C
	Series D
	Series E
	Debt Financing/Debt
	Late Private Equity (above €20 million)
	Late Venture Capital
Exit	IPO (Initial Public Offering)
	Post-IPO Equity
	Acquisition
	Merger
	Secondary market

Source: Technopolis Group

The Table below summarises the indicator that has been constructed as a result of this analysis.

Table 7: Indicator table

Indicator	Timeline	Data source
Private equity and Venture Capital investment in the green and digital transition **Value of private equity and VC funding raised per green and digital technology and per industrial ecosystem**	2015 - 2024	Crunchbase and Net Zero Insights

Source: Technopolis Group

3.2.1.2. Firm investments in green and digital technologies

Rationale: One of the key indicators for capturing the green and digital transition is the investment of firms across different industrial ecosystems in green and digital technologies as well as circular economy business models. Investments reflect a firm's commitment to

the objectives of transition and to new business practices that drive forward developments within their respective industrial ecosystems.

Methodology: In order to capture firm investments, we combine data obtained from the survey (where we asked companies about their level of investment in specific green and digital technologies) and Orbis data that offers detailed financial information on companies, encompassing revenues, assets, and market capitalisation. More specifically, we use data on R&D private expenditures of companies and combine this with information from the EMI survey. This allows for an extrapolation at industry level and providing a comprehensive picture of how different industrial ecosystems are investing in the green and digital transition. The Table below summarises the indicator that has been constructed as a result of this analysis.

Table 8: Indicator table

Indicator	Timeline	Data source
Investment costs in the green and digital transition	2023-2024	Survey and Orbis data combined

Source: Technopolis Group based on Orbis and the EMI Enterprise Survey

3.2.2. Public investments

3.2.2.1. Cohesio

Rationale: A key source of public funding that enables the green and digital transition is the EU's regional development funds. These funds support economic development and cohesion across the European Union, particularly in less developed regions. By allocating resources to projects that promote sustainability and digital innovation related to specific industrial ecosystems, the regional development funds play a critical role in driving forward the green and digital agendas. The Cohesion Dataset[10] provides descriptive, categorical, and financial information on the European Regional Development Fund (ERDF) and Cohesion Fund operations funded by 215 operational programmes and 73 cooperation programmes under all Thematic Objectives during the 2014-2020 programming period.

Methodology: For this analysis, two data sources have been used and merged: the Cohesion Open Data maintained by the European Commission and the Kohesio data that contains more than 1.7 million projects and approximately 500 000 beneficiaries financed throughout the funding period 2014–2020. The project level data relates primarily to different forms of financial inputs (planned and implemented), EU payment data and to outputs and result indicators of the physical results of the funded programmes. At the time of writing this report, only data for 2024-2020 were available and data for the 2021-2027 programming period can be only added towards the end of this year.

In order to identify projects relevant for industrial ecosystems, we used the codes of economic activity and conducted additional keyword searches in the project descriptions. The green and digital transition were filtered in the same manner, using a selected list of green and digital keywords that were also constructed for other parts of the data collection in this project.

[10] https://data.europa.eu/en/news-events/news/cohesion-open-data-platform

Table 9: Indicator table

Indicator	Timeline	Data source
ERDF funding allocated to projects that support the green transition	2015-2022	Cohesio
ERDF funding allocated to projects that support the digital transition	2015-2022	Cohesio

Source: Technopolis Group based on Cohesio

3.2.2.2. Research and innovation investments at EU level

Rationale: The trends and developments in research and innovation investments at EU level have been analysed within industrial ecosystems using data from Horizon Europe and Horizon 2020 programmes.

Methodology: The data was accessed via CORDIS[11], the European Commission's platform for research and innovation funding, to extract specific insights related to the research and innovation funding programmes. Project details such as identification number, title, cost, funding received, and objectives have been downloaded. The data have been merged with the relevant EuroSciVoc data[12]. EuroSciVoc connects projects to relevant scientific concepts, providing a deeper understanding of the research focus. To ensure data accuracy and facilitate keyword searches, project objectives have been subjected to lemmatisation[13], a process that converts words to their base form. Finally, a thorough error check was conducted to identify and rectify inconsistencies.

The green and digital transition was captured by key terms within the EuroSciVoc and additional keywords. These terms have been selected through a combination of analysing the EuroSciVoc taxonomy (e.g., social sciences, engineering and technology) and keyword searches, found through desk research. A scoring system has been implemented to determine a project's relevance to the chosen ecosystem. This system assigns points based on the presence of relevant keywords and EuroSciVoc concepts within project descriptions. Projects need to achieve a minimum score, typically involving a combination of both, to be considered part of the ecosystem.

To ensure a more accurate allocation of project costs and funding, a fractional counting approach has been implemented. This involves assigning the root categories of each project based on their EuroSciVoc taxonomy to each industrial ecosystem based on their defining terms. Each project has been categorised based on its root categories and the fraction of all the relevant categories has been determined. The project funding dedicated to each industrial ecosystem has been calculated based on the fractions relevant for the industry in the case of each project. This ensures a more accurate allocation of resources based on their relevance to the ecosystem's objectives. For example, an R&I project might involve textile companies developing innovative solutions for construction. In this case, a percentage of project funding is allocated to the textile industrial ecosystem and another percentage to the construction ecosystem.

Table 10: Indicator table

Indicator	Timeline	Data source
Total project costs	2014-2024	CORDA
Total funding	2014-2024	CORDA

[11] Horizon programmes download: https://cordis.europa.eu/projects
[12] https://op.europa.eu/de/web/eu-vocabularies/euroscivoc
[13] https://dictionary.cambridge.org/de/worterbuch/englisch/lemmatization

Number of projects	2014-2024	CORDA

Source: Technopolis Group based on CORDA

The indicators are further broken down by year, technology, and green or digital transition. This breakdown offers an overview of resource allocation, project activity, and technological advancements within the specific R&I ecosystem funded by the grant programme.

3.3. Technology generation

3.3.1. Patent analysis

Rationale:

Patent data are widely used to track technological development activities. In the context of the industrial ecosystems studied in this project, technology generation—and hence patenting—occurs in a relatively limited number of ecosystems, while others primarily benefit from technologies generated elsewhere.

Methodology:

Patent data were calculated separately at the level of technologies and industrial ecosystems. First, it is important to focus on the level of technologies, as technologies such as Artificial Intelligence, low-carbon technologies, cloud computing are general-purpose technologies, applicable in many if not all industrial ecosystems. Technology development is thus not specific to individual ecosystems but drives industrial transformation in a broader sense. Simply focusing on technologies developed by firms within a specific ecosystem would substantially underestimate the overall scope of technologies available and relevant to that ecosystem. Second, it is nonetheless relevant to understand the extent to which firms within a specific industrial ecosystem contribute to technological development in various ways and across different technological fields that broadly belong to the ecosystem. Therefore, both approaches are used side by side in the reports but are mixed only for very specific purposes to avoid confusing signals.

Moreover, it is important to acknowledge that there is a rather fundamental difference between technology generating ecosystems and those that primarily deploy technology. For the former, a patent analysis at ecosystem level is essential and useful. For the latter, like e.g. the tourism ecosystem it is not appropriate. While, obviously, a lot of digital and green technologies are being applied in the transformation of the tourism or the cultural and creative industry, only a tiny fraction of those is generated within these ecosystems. Hence, it would be misleading to document their technology generation capacity directly.

To ensure that only the most relevant patents are considered, the analysis focuses on 'transnational patents' (Frietsch/Schmoch, 2010) in line with the preceding Advanced Technologies for Industry studies and the first phase of this project, i.e. on PCT/WIPO filings or direct applications at the EPO, excluding double counts. These patent applications stand out by being a) more expensive (application fee & potential maintenance) than others and b) protecting intellectual property at more than one patent office, i.e. potentially securing more than one national market. By using an effective, yet costly procedure that would not naturally be chosen unless the intention to protect IP was sincere. In addition, using transnational patents for the analyses ensures that patents by all filing countries are measured at the same scale, without home advantages at domestic offices distorting the general picture. The patent analysis is conducted on an extended version of the EPO's Worldwide Patent Statistical Database that Fraunhofer ISI implemented locally.

For the analyses at the level of technologies, this study continues to use existing definitions developed for key enabling technologies and digital technologies in earlier studies. These are regularly updated on a technical level as IPC classes continue to change but left unchanged at a level of substance to ensure comparability over time. In addition, new

definitions for green technologies, recycling and specific digital technologies (blockchain) have been included. Where possible, these definitions are grounded in published approaches - which may be merits and drawbacks.

In order to address aspects of digitalisation and greening as well as to acknowledge the European Commission's past revisions of the key enabling technologies, the report continues to use the aggregate classes introduced in the first phase of this project.

Different from the approach taken therein, the analysis at ecosystem level is during this phase enabled through a matching of Patstat data with information from Moody's Orbis database which allows the attribution of each patent to an organisation which, in Orbis, bears a specific NACE codes. Thus, the overt majority of patents can be assigned to industrial ecosystems based on the ecosystem<>NACE classification published in Annex to the 2022 Annual Single Market Report (pp. 69-71).

This novel approach enables a detailed and robust analysis of technology generation that differentiates by ecosystems (as delineated by NACE) and technology fields (as delineated by IPC). In the 2024 reports, this will replace an earlier, more preliminary solution. As mentioned above, however, these differentiated data will only be produced for specific ecosystems where: a) the overall amount of technology generation justifies further differentiation, and b) the ecosystem can conceptually be considered a technology-generating one, ensuring that the analysis has a substantive basis.

Table 11: Indicator table

Indicator	Timeline	Data source
Share of field specific national patent applications in field specific world total	2010-2022	Fraunhofer ISI analysis based on EPO PATSTAT and Moody's ORBIS
Share of field specific patent applications in overall national total	2010-2022	Fraunhofer ISI analysis based on EPO PATSTAT and Moody's ORBIS
Field specialisation in patent applications (Relation of share of national field specific patent applications in overall national total to worldwide field specific patent applications in overall world total)	2010-2022	Fraunhofer ISI analysis based on EPO PATSTAT and Moody's ORBIS

Source: Fraunhofer ISI

3.4. Skills

3.4.1. Skills supply

Rationale: Presence of professionals with skills related to the twin transition and to advanced technologies is key in the transformation of the industry. In the view of the present study, the uptake of advanced technologies and the spread of the twin transition in the different industrial ecosystems in focus depend partly on their ability to attract/retain/upskill the adequate skilled workforce. Monitoring the specific digital or green transition skills of professionals employed in a specific industry has an overall lack of data and cannot be tracked neither by Eurostat nor any other robust statistics. This is why, this study relies on the exploratory data source of LinkedIn, the largest professional online network with more than 86 million of European users.

Methodology: The LinkedIn data has been calculated on this entire professionals' base and is extremely timely as it represents live the state of play of the LinkedIn platform. To harvest the data from LinkedIn, keywords capturing twin transition skills have been defined per industrial ecosystems, and queries have subsequently been constructed to filter the database by location and industrial ecosystems. Industrial ecosystems have been defined

according to LinkedIn classification of industries, in parallel to the associated NACE codes (Rev 2). The outcome of the queries is used to assess the share of professionals within each industrial ecosystems who appear to master twin transition and advanced technologies skills. Furthermore, the growth rate of this highly skilled workforce in the ecosystem reflects the pace of the industrial transformation.

More specifically, green and digital skills have been defined as below (the list of keywords used as part of the analysis is included in Appendix C):

Green skills have been defined as skills related to environmental protection, environmental services, resource efficiency, biodiversity, low carbon technologies, renewable energy, the circular economy, waste management, management of food waste, and clean production technologies and business models related skills[14].

Moderate digital skills have been defined following Cedefop[15] notably including "*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)"*.

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 including artificial intelligence and big data, cloud computing, robotics, Internet of Things, augmented and virtual reality and blockchain.

By its nature as a voluntary professional online network, LinkedIn presents biases and data needs correction in order to confidently generalise the findings to the total population and allow for comparisons. The biases of the LinkedIn data arise from a varying popularity of LinkedIn across different subsets of the population and result in different degrees of representativeness of the LinkedIn population according to their country, their sector of activity, their gender and their education level. To assess these representativeness biases, we compare the LinkedIn population and the actual active population in terms of industry size and country using Eurostat data. We also assess the information in LinkedIn on the professionals' function i.e. whether in engineering, sales, information technologies, business development, operations, etc. to better comprehend the coverage within each industrial ecosystem.

3.4.2. Skills demand

Rationale: Cedefop Skills intelligence provides valuable insights into the job market and skills demand through its dataset 'online job advertisement'. This extensive tool comprises 530 online job advertisement sources from 424 distinct open-access websites, covering EU Member States.

Methodology: The dataset, which has been continuously updated since July 2018, analyses over 100 million online job ads, offering information on the most sought-after occupations and skills across European countries. By utilising internationally recognized classifications such as ISCO-08 for occupations, ESCO for skills, and NACE rev. 2 for sectors, the dataset provides comprehensive and up-to-date information for the 27 EU Member States and other European countries. Access to the data is facilitated through Web Intelligence Hub (WIH).

In our analysis, skills are filtered by pre-defined green and digital skills, while we use the NACE rev. 2 to define each industrial ecosystem. The green predefined skills are from ESCO v1.1[16] and the digital are predefined from ESCO v1.1.1[17] which is currently being updated.

[14] https://www.cedefop.europa.eu/files/3057_en.pdf
[15] https://www.cedefop.europa.eu/en/data-insights/digital-skills-challenges-and-opportunities
[16] ESCO green skills download: https://esco.ec.europa.eu/en/use-esco/download
[17] ESCO digital skills download: https://esco.ec.europa.eu/en/use-esco/download

To further complement our analysis, we created our own taxonomy of advanced digital skills.

The period in focus was 2019 until 2022 to allow for an analysis over time. The growth was measured both in terms of the absolute number of adverts, and their share in total notices per industrial ecosystem. The outcome of the queries is used to assess the share of job adverts within each industrial ecosystem which demand the transition skills. Furthermore, the growth rate of the job advertisements in the ecosystem reflects the change in demand for the companies for the transition skills.

Nonetheless, there are some limitations to the database due to its novel and experimental data which leads us to be precarious when analysing the data. It is important to note that all online job advertisements prior to the year 2022 (specifically, from 2018 to 2021) are desecrated due to updates in methodologies for analysing online job advertisements and revising ESCO skill classifications. Despite utilising up-to-date technologies, the tools used for data processing may still be prone to errors. Constant improvement is required for the ontologies developed and utilised to sort and organize the complex and diverse universe of online job advertisement data, which affects our ability to track trends over time. Online job advertisements represent only a portion of the overall job demand, as not all job vacancies are advertised online. It is also worth mentioning that the validation of the data is limited due to restricted access to the source data. Therefore, the analysis on skills demand within the framework of this project should be taken as an estimation or proxy rather than a robust result.

Table 12: Indicator table

Indicator	Timeline	Data source
Share of professionals with digital and green transition skills employed in industrial ecosystems	2019-2024	LinkedIn
Share of job advertisements with requirements for digital and green transition skills per industrial ecosystem	2019-2023	Cedefop SkillsOvate

Source: Technopolis Group based on LinkedIn and Cedefop

3.5. Sustainable competitiveness

3.5.1. Production and trade data

Rationale: Prodcom data tracks the production of goods in the European Union, providing detailed statistics on the manufacturing of products in industrial ecosystems. The data can be used to estimate to what extent green and digital technologies have been integrated within industrial products by focusing on specific components. New technologies are viewed as opportunities to boost productivity and positively impact economic growth, employment, and the environment. Production data shows how much of these technology-related products are being manufactured within the manufacturing-based industrial ecosystems. Prodcom analysis is not conducted for predominantly service based industrial ecosystems (Culture and Creative industries; Retail; Tourism; Proximity and Social Economy), due to non-availability of data.

Methodology: The production indicators are calculated based on product-level data from the Eurostat's Prodcom database. Prodcom is the title of the EU production statistics for Mining, Quarrying and Manufacturing, i.e. Sections B and C of the Statistical Classification of Economic Activities in the European Community (NACE Rev. 2). The headings of the Prodcom list are derived from the Harmonized System (HS) or the Combined Nomenclature (CN), which thus enables comparisons to be made between production and trade statistics. Similar to the earlier ATI project, attention has been devoted to aligning the definitions and analysis of the HS and Prodcom based analysis.

The selection of relevant Prodcom codes for the production of manufacturing goods was reviewed to ensure alignment with the EU industrial ecosystems and to contribute to the assessment of progress towards the green and digital transition. Production data provides information on the ability of EU countries to realise and use green and digital technologies to improve their overall competitiveness and apply these technologies in target application areas. They provide insight in the production of the technology to other application areas and wider sectors and highlight to what extent the EU can use the potential of green and digital technologies to improve its competitiveness by manufacturing technology-based products and applying them in the production of manufacturing goods. As production data is sometimes confidential for certain technologies and particular Member States, a close collaboration with Eurostat was needed.

Trade data provide a relevant indication of industrial development at the Technology Readiness Level - TRL 8-9 level. First, they inform on countries' comparative and competitive advantage in specific product areas. In today's interconnected global economy, however, that indication is certainly far less direct than suggested bv classic trade theory and figures subject to various additional factors of influence such as whether the country is an assembly location for goods it cannot design or even simply a shipping hub. That notwithstanding, export strengths in certain technological areas still mark a specific relevance of technology relevant goods for a particular economy. Overall, they among the most reliable indicators of many nations' competitive performance.

One of the most relevant qualifications of sheer export figures is the parallel consideration of imports - which allows to filter assembly and shipping hub situation. The analysis therefore focuses primarily on trade balances rather than gross exports. By putting exports in relation to parallel imports, it is at least to a degree possible to assess whether a country displays genuine strengths grounded in technological capacities. In addition, a careful analysis of trade data is one of the few available tools to at least trace international production chains. For example, they can help reveal how technologically strong nations are nonetheless intricately involved in supply chains that involve both substantial imports and relevant exports.

Second, a careful analysis of trade data is one of the few reliable tools available to trace international production chains. For example, they can help reveal how technologically strong nations are nonetheless intricately involved in supply chains that involve both substantial imports and relevant exports.

As during the first phase of the project, final delineations are provided for:

- all non-service ecosystems as defined by the European Union to assess the full amount of trade affected when addressing policy efforts to a specific ecosystem
- Based on an embeddedness logic the complete existing list of technologies relevant for digitalisation and greening

In practical terms, technology and ecosystem specific trade portfolios were be defined based on HS (Harmonised System) codes. After a long history of projects reporting trade figures for different KETs fields, all existing definitions were reviewed manually in close consultation with the team performing the PRODCOM analysis. The need for this more detailed review emerged as technologies and related products have developed further. In consequence, the final definition reported in Annex, draws on a revision of definitions available from earlier projects and some newly developed for example recycling and clean production technologies. Finally, the agreed definitions were transformed into bespoke queries and trade data was generated from an in-house version of the UN's COMTRADE database that Fraunhofer ISI maintains.

As in the case of production data, the assignment of product categories to technologies follows an embeddedness logic. As some key technologies like artificial intelligence, big data and digital security lack a clear material basis, the best possible approach is to define lists of "goods relevant for a specific technology”, i.e. in the listed cases certain microchips, storage modules or network equipment that stand in close relation to these technologies, into which they need to be 'embedded'. For others the problem is less directly obvious,

specific technology fields can in any case not be as precisely represented by product classes as is possible in other domains, such as patenting.

The trade analysis presented in this study and the reports pertaining to it thus primarily show whether the European Union or specific other countries have the material basis to develop and implement activities in the technology areas of interest for the analysis. It fully acknowledges that the core contribution in many of them is, in the meantime of an immaterial nature and cannot be captured by production or trade data. To cover those, other indicators, such as start-up activities and investment have been included in the analysis.

Table 13: Indicator table

Indicator	Timeline	Data source
Production global competitiveness: country share in global production of manufacturing goods	2008-2023	Prodcom
Production country significance: Share of production in AT over a country's total production of manufacturing goods	2008-2023	Prodcom
Trade balance: difference between exports and imports in relation to the total trade volume (exports plus imports) of a country	2015-2023	UNCOMTRADE

Source: IDEA Consult

3.5.2. Environmental impact

Rationale: The environmental impact of industrial ecosystems is measured via the environmental impact of both production and consumption, using the Exiobase[18] and Figaro datasets.

Exiobase

As a global input-output database, Exiobase maps out global value chains and therefore enables analysis not only of sectoral production (as, for instance, GDP does), but also of the content of consumption, taking into account not only the direct products consumed but those needed as intermediate inputs, whether directly or indirectly. Additionally, Exiobase is an environmentally enhanced database, which means it is particularly designed to analyse the environmental impact accounting for the entirety of a product's value chain.

Methodology: While a few global input-output databases exist (such as the OECD's ICIO[19], EORA[20] or WIOD[21]), Exiobase presents a number of advantages: it is relatively up to date (data from 1995 to 2022), has good geographical coverage (44 countries including the whole EU – and estimates for the rest of the world), significant detail at the industry level (163 industries, albeit tracking physical production better than services), and most of all, integrated environmental data for 417 emission categories and 662 material and resource categories. As a major research output produced by a European consortium funded by European research framework programs, Exiobase is internationally recognised as a leading reference for measuring environmental footprints, with its data used by the

[18] https://www.exiobase.eu/index.php/about-exiobase
[19] https://www.oecd.org/sti/ind/inter-country-input-output-tables.htm
[20] https://worldmrio.com/eora/
[21] https://www.rug.nl/ggdc/valuechain/wiod/?lang=en

European Environmental Agency[22], the EC/JRC[23], Eurostat[24], and by the European Commission to propose the regulation on carbon border adjustment mechanisms[25].

To identify Industrial Ecosystems (IE), these were mapped against relevant sectors in Exiobase, with the environmental impact of these sectors summed up to produce the estimated at the level of the IEs. For each of these, the following environmental impacts are measured: greenhouse gas emissions, emissions of particulate matter, materials extraction, land use, blue water consumption, and biodiversity loss.

Exiobase allows the comparison of both the production and consumption footprints of an industrial ecosystem. For example, the process of producing of a shirt in the EU (counted in the Textile industrial ecosystem) would create greenhouse gas emissions – this is the production impact. However, we can delve deeper with Exiobase, and consider the greenhouse gas emissions of the inputs used in producing the shirt, whether from within the EU or imported: cotton, chemical dyes, electricity, etc. In turn, cotton has its own inputs: water, fertilizer, etc. The consumption-based measure takes into account the environmental impact of the entirety of these inputs that are necessary to the production of a shirt ultimately purchased by an EU consumer. In the 2025 edition of EMI Exiobase indicators will be used for production footprints of industrial ecosystems.

While Exiobase provides powerful insights, it is important to also recognise its limitations. As is usual of global input-output databases, its measurement of physical product flows is much more granular than for services, which means that estimates for more service-based Industrial Ecosystems are less precise. Furthermore, the original Exiobase data only extends to 2011, with data to 2022 produced by a nowcast. More generally, input-output database combines and attempt to harmonise data from a wide range of sources, which means they can be less accurate and up to date than datasets that are tailor-made for a specific geographical zone or theme. It is therefore recommended to treat the findings of Exiobase more as estimates of magnitude of impact, rather than precise statistical measurement.

FIGARO

FIGARO ("Full International and Global Accounts for Research in input-Output analysis") is a database developed by Eurostat and is a multi-regional input-output database (similar to Exiobase, the OECD ICIO, and EORA). It is produced by Eurostat using EU national accounts data, with a lag of 2 years. Recently, it has started publishing data on environmental footprints, which makes it suitable for use in EMI. A comparison between Exiobase and FIGARO provided in the table below showcases the complementarities between the two approaches.

Dimension	Exiobase	FIGARO	Comments
Sector coverage	163 sectors, 200 products	64 sectors and products	Exiobase is more detailed, but a comparison of sector coverage shows that FIGARO generally covers well the NACE codes that map to EMI industrial ecosystems. Furthermore, FIGARO is already organised by NACE codes, which makes the mapping to EMI easier
Country coverage	EU27 + 18 non-EU countries	EU27 + 17 non-EU countries	Almost identical country coverage, with small differences in non-EU country coverage
Data reliability	Nowcast input-output table	Consistent with EU national accounts, updated yearly	FIGARO's major advantage is that it is produced by Eurostat, therefore consistent with EU national accounts, and updated yearly

[22] https://www.eea.europa.eu/data-and-maps/data/external/exiobase
[23] https://www.sciencedirect.com/science/article/pii/S0959652619301519?via%3Dihub
[24] https://ec.europa.eu/eurostat/web/products-statistical-working-papers/-/ks-tc-19-002
[25] EC (2021) REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL. Establishing a carbon border adjustment mechanism. COM(2021) 564 final.

Dimension	Exiobase	FIGARO	Comments
Time series	1995-2022	2010-2022	Exiobase has a longer time series in theory, but in practice it is nowcast for more recent years. FIGARO is properly up to date (with a 2-year lag), which is a major advantage.
Environmental footprints	Hundreds of environmental impact indicators	7 indicators, but only covering emissions	Exiobase has a much broader coverage than FIGARO
Production vs consumption	Access to both the environmental footprint and the factors.	Only consumption footprint, as far as I can tell	Exiobase gives more options in terms of how to break down data into production vs consumption, and options to make own calculations. FIGARO so far only allows reporting of consumption.

The selection of indicators from Exiobase and FIGARO are listed below.

Table 14: Indicator table

Indicator	Definition	Timeline	Data source
Greenhouse gas emissions	Emissions of greenhouse gases (as defined in IPCC AR5) converted to CO2 equivalents using the GWP100 conversion (Global Warming Potential for a 100-year time horizon) (megatons CO2)	2010-2022	FIGARO (consumption)
Emissions of particulate matter	Emissions of PM10 and PM25 (megatons PM10, PM25)	2010-2022	Exiobase (consumption and production)
Materials extraction (used and unused)	Used and unused crops and crops residue, grazing and fodder, forestry and timber, fisheries, non-metallic minerals, iron ore, non-ferous metal ores, coal and peat, and oil and gas (megatons)	2010-2022	Exiobase (consumption and production)
Land use	Land use for crop, forest or pasture (10^{12} km^2)	2010-2022	Exiobase (consumption)
Blue water consumption	Consumption of blue water (fresh surface or groundwater) (10^{18} m^3)	2010-2022	Exiobase (consumption and production)
Biodiversity loss	Damage to the ecosystem by ecotoxic emissions (10^{12} PDF * m^2 * yr)	2010-2022	Exiobase (consumption and production)
Greenhouse gases	Greenhouse gases (CO2, N2O in CO2 equivalent, CH4 in CO2 equivalent, HFC in CO2 equivalent, PFC in CO2 equivalent, SF6 in CO2 equivalent, NF3 in CO2 equivalent)	2014-2023	Eurostat Air emissions accounts by NACE Rev. 2 activity

Source: Technopolis Group based on Exiobase

4. Composite indicators

The conceptual framework of EMI builds upon the literature on socio-techno-economic systems (Wieczorek et Hekkert, 2012; Geels, 2018; Long et Holmen, 2021) and the Industrial Forum's 'Blueprint for the Development of Transition Pathways'.

The corresponding monitoring framework contains four dimensions covering key aspects of the twin transition and the move to greater resilience: (1) **Sustainable competitiveness** measuring progress in reducing environmental impacts and the impact of digital technologies on productivity, (2) **Efforts** reflected in the uptake and generation of technologies or solutions and private investments and **Framework conditions** including (3) **Public funding** and (4) **Skills**.

The indicators framework contains **37 indicators**, with the highest level of aggregation composed of **8 dimensions, split between Green and Digital transition** composite indicators.

Table 15 Indicator framework - EMI Composites

Indicator label	Indicator	Source
SUSTAINABLE COMPETITIVENESS		
1.1 Progress in alleviating environmental pressures on resource consumption		
1.1.1 Material extraction	Used and unused crops and crops residue, grazing and fodder, forestry and timber, fisheries, non-metallic minerals, iron ore, non-ferous metal ores, coal and peat, and oil and gas (G Tons) (growth - indexed to year 2017)	Exiobase
1.1.2 Blue water use	Consumption of blue water (fresh surface or groundwater) (1018 m3) (growth - indexed to year 2017)	Exiobase
1.2 Progress in reducing environmental pressures on climate and biodiversity		
1.2.1 GHG emissions	Emissions of greenhouse gases (as defined in IPCC AR5) converted to CO2 equivalents using the GWP100 conversion (Global Warming Potential for a 100-year time horizon) (G Tons CO2) (growth - indexed to year 2017)	Exiobase
1.2.2 Biodiversity	Damage to the ecosystem by ecotoxic emissions (1012 PDF * m2 * yr) (growth - indexed to year 2017)	Exiobase
1.2.3 Particulate matter emissions	Particulate matter consists of a mixture droplets smaller than 2.5 micrometers and 10 micrometers and are emited locally by various sources such as vehicle exhaust, smoke, road dust, vehicles and airplane tyres, etc. The annual volume in Megatonnes comes from the Exiobase 3.8.2 production-based account (growth - indexed to year 2017)	Exiobase
1.3 Digital impacts		
1.3.1 Productivity gains	Digital tech driven productivity increase (Share in total SMEs - average of all technologies)	2024 EMI enterprise survey

Indicator label	Indicator	Source
1.3.2 Production costs	Digital tech enabled Cost Reduction (Share in total SMEs - average of all technologies)	2024 EMI enterprise survey
EFFORTS		
2.1 Green transition commitment		
2.1.1 Green technology adoption	Companies adopting green technologies (share in total companies)	2024 EMI enterprise survey
2.1.2 Strategy to reduce carbon footprint and become climate neutral or negative	Companies with a concrete strategy in place to reduce carbon footprint and become climate neutral or negative (share in total SMEs)	2024 EMI enterprise survey
2.2 Circular economy efforts		
2.2.1 Switching to greener suppliers of materials	SMEs switching to greener suppliers of materials	Eurobarometer
2.2.2 Recycling, by reusing material or waste within the company	SMEs recycling by reusing material or waste	Eurobarometer
2.2.3 Designing products that are easier to maintain, repair or reuse	SMEs designing products that are easier to maintain	Eurobarometer
2.3 Waste management efforts		
2.3.1 Minimising waste	SMEs taking action to minimise waste	Eurobarometer
2.3.2 Selling your residues and waste to another company	SMEs selling residues and waste to another company	Eurobarometer
2.4 Resource efficiency efforts		
2.4.1 Saving water	SMEs taking action to save water (share in total SMEs)	Eurobarometer
2.4.2 Saving energy	SMEs taking action to save energy (share in total SMEs)	Eurobarometer
2.4.3 Saving materials	SMEs taking action to save material (share in total SMEs)	Eurobarometer
2.5 Private investments in green transition		
2.5.1 VC and private equity investments in green tech	Volume of VC and private equity invested in companies generating green transition technologies (share in total VC)	Crunchbase
2.5.2 Green transition investment share	Average share of turnover invested by companies for their green transition (share in turnover)	2024 EMI enterprise survey
2.6 Green technology generation		

Indicator label	Indicator	Source
2.6.1 Green transition technology generation by start-ups	Share of tech start-ups generating green transition technologies (share of startups)	Crunchbase
2.6.2 Green patents	Patent applications in green technologies (3-Year Averages of Share of green Patents in All Patents Filed in Respective National Ecosystem)	Patstat
2.7 Digital transition commitment		
2.7.1 Digital technology adoption	Companies adopting digital technologies (share in total SMEs)	2024 EMI enterprise survey
2.7.2 Digital transformation strategy	Enterprises with a concrete strategy in place for digital transformation (share in total SMEs)	2024 EMI enterprise survey
2.8 Private Investments in digital transition		
2.8.1 VC and private equity investments in digital tech	Volume of VC and private equity invested in companies generating digital technologies (share in total VC)	Crunchbase
2.8.2 Digital transition investment share	Average Share of turnover invested by companies for their digital transition (share in turnover)	2024 EMI enterprise survey
2.9 Digital technology generation		
2.9.1 Digital technology generation by start-ups	Number of technology startups generating digital transition technologies (share of startups)	Crunchbase
2.9.2 Digital patents	Patent applications in digital technologies (3-Year Averages of Share of green Patents in All Patents Filed in Respective National Ecosystem)	Patstat
FRAMEWORK CONDITIONS		
Investments		
3.1 Investments in green transition		
3.1.1 EU R&D funding in green transition	EU R&D funding in green transition projects (share of value in total funding)	Cordis
3.1.2 ERDF Funding in green transition	ERDF funding in green transition projects (share of value in total ERDF funding in EUR)	Kohesio
3.2 Investments in digital transition		
3.2.1 EU R&D funding in digital transition	EU R&D funding in digital transitions (share of value in total funding in EUR)	Cordis

Indicator label	Indicator	Source
3.2.2 ERDF Funding in digital transition	ERDF funding in digital transitions (share of value in total ERDF funding in EUR)	Kohesio
Skills		
3.1 Green skills		
3.1.1 Green skills supply	Professionals with green transition skills employed in industrial ecosystems	LinkedIn
3.1.2 Green skills demand	Job advertisements with requirements for green transition skills per industrial ecosystem (share in total advertisments)	Cedefop Online Job Advertisment tables (OJA)
3.1.3 Green skills roles	Share of SMEs with a significant focus in jobs relevant for environment protection, environmental sustainability (between 11 and 50 employees)	2024 EMI enterprise survey
4.2 Digital skills		
4.2.1 Digital skills supply	Professionals with digital transition skills employed in industrial ecosystems (share in total professionals)	LinkedIn
4.2.2 Digital skills demand	Job advertisements with requirements for digital transition skills per industrial ecosystem (share in total advertisements)	Cedefop Online Job Advertisment tables (OJA)
4.2.3 Digital skills roles	Share of SMEs with a significant focus in digital jobs or IT-related roles (between 11 and 50 employees) (share in total SMEs)	2024 EMI enterprise survey

Source: Technopolis Group

The process of creating industrial transition composite indicators followed a standard procedure as recommended by the JRC/OECD Handbook on Composite Indicators and implemented by the COINr R package.

The time series vary across indicators, but for each indicator, the latest available data are used. The analytical steps to construct the composites in brief include the following:

- Data treatment: namely check for missing data, outliers and scale or directional adjustments.
- Normalisation: Min - max normalisation is used. All the resulting observations lie between 0 (lowest) and 1(highest). The minimum and maximum observations refer to the minimum and maximum observation among all industrial ecosystems.
- Performance: interpretation of correlation matrix (check for very high correlations and negative correlations).
- Aggregation: a composite is calculated as the unweighted average of the re-scaled scores for all indicators where all indicators receive the same weight. The composites are calculated for each of the sub-sub-dimensions and then per sub-dimension for green and digital transition.

5. Technology Centre mapping

In addition to the quantitative analysis and monitoring of the twin transition of industrial ecosystems, data have been collected on Technology Centres as part of the EMI project. 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. To this end, this project includes an exercise on mapping Technology Centres across the EU.

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.

The mapping includes the following list of technologies covered under this project:

- Digital transition
  - Advanced Manufacturing & Robotics
  - Artificial Intelligence and Big Data
  - Augmented and virtual reality
  - Blockchain
  - Digital Security & Networks/Cybersecurity
  - Internet of Things
  - Micro- and Nanoelectronics & Photonics
- Green transition
  - Advanced Materials and Nanotechnology
  - Biotechnology including Medical Biotechnology
  - Energy Saving Technologies
  - Renewable Energy Technologies (including solar, wind, batteries, geothermal, hydropower, biomass, hydrogen)
  - Clean Production Technologies
  - Recycling technologies

An additional search was performed to identify Technology Centres that comply with the eligibility criteria to be included in the mapping (see Box 1).

Box 1: Eligibility criteria

Technology Centres have to comply with 3 qualitative criteria

- Provide services to industry and SMEs
- Be active in at least one of the Advanced Technologies for Industry
- Be active in the higher Technology Readiness Levels (TRL) -have activities in TRL5, TRL6, TRL 7 or TRL 8

Technology Centres have to comply with at least 2 additional quantitative criteria among the following 4:

- More than 10 projects with SMEs in the last two years.
- More than 2 major investments in equipment for close-to-market R&D activities with industry in the last 3 years. The Centre should provide a short description of these investments (type, functionality and investment amount)
- At least 15% from industrial funding in the total annual funding of the Centre in the last 2 years.
- At least 7% from projects with SMEs in the total turnover of the Centre in the last 2 years.

6. Data quality measures

In order to ensure data quality, the following measures are implemented:

Table 16: Data validation process

Quality Criteria	Action
Coverage of technologies and industrial ecosystems	**The accuracy of codes** applied to identify the specific advanced green and digital transition related technologies, and the industrial ecosystems is checked by a random sample manually in the case of each download.
Completeness	**The completeness of data** is verified in terms of missing values and ensured that each dataset is fit for analysis and reporting.
Validity of data	**The validity of data files is checked consistently in order to detect** any erroneous values in the data (syntactic accuracy).
Consistency	It is ensured that the **data follows expected formats, relationships, and rules across all datasets**,
Timeliness	The sources are checked to ensure that the **most recent available year** have been collected.
Accessibility and Clarity	**Compilation of clear metadata description** (including full provenance information for reproducibility),

Appendix A: Definitions of Green and Digital Technologies

The monitoring framework applies a technological lens in the analysis of industrial ecosystems whereby most of the indicators are calculated not just per ecosystem but type of green and digital technology at the same time (whenever the technology is relevant for the industrial ecosystem).

Advanced Manufacturing Technology

Advanced Manufacturing technologies (AMTs) are broad technological bundles which support the design and fabrication of products, a higher level of connectivity, and the optimised planning of resources[26]. Overall, they improve products or processes that drive innovation in manufacturing. It covers two types of technologies: process technologies to produce other advanced technologies or manufactured products, and process technologies based on Robotics, automation technology or computer-integrated manufacturing that support the manufacturing processes. For the former, such process technology typically relates to production apparatus, equipment and procedures for the manufacture of specific materials, components, or final products. For the latter, process technology includes measuring, control and testing devices for machines, machine tools and various areas of automated or IT-based manufacturing technology[27].

Advanced Materials

Advanced Materials are materials that respond to changes to their environment and as a result, go through a material property change[28]. They reduce the substitution costs of existing materials and add higher value to products and services. They are applied in a wide variety of fields, e.g. in aerospace, transport, building and health care. They facilitate recycling, lowering the carbon footprint and energy demand as well as limiting the need for raw materials that are scarce in Europe[29].

Artificial Intelligence

Artificial intelligence (AI) systems are software (and possibly also hardware) systems designed by humans that, given a complex goal, act in the physical or digital dimension by perceiving their environment through data acquisition, interpreting the collected structured or unstructured data, reasoning on the knowledge, or processing the information, derived from this data and deciding the best action(s) to take to achieve the given goal. AI systems can either use symbolic rules or learn a numeric model, and they can also adapt their behaviour by analysing how the environment is affected by their previous actions[30]. Artificial Intelligence is a heterogenous field in terms of its technology base. While some aspects like sensors, chips, robots as well as certain applications like autonomous driving, logistics or medical instruments refer to hardware components, a relevant part of AI is rooted in algorithms and software[31].

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[26] Stornelli, A., Ozcan, S. and Simms, C., 2021. Advanced manufacturing technology adoption and innovation: A systematic literature review on barriers, enablers, and innovation types. Research Policy, 50(6), p.104229.
[27] EC EISMEA/GROW (2021) Advanced Technologies for Industries – Methodological Report. Indicator Framework and Data Calculations. ISBN 978-92-9202-952-4. doi:10.2826/911991.
[28] Ryan, K.R., Down, M.P. and Banks, C.E., 2021. Future of additive manufacturing: Overview of 4D and 3D printed smart and advanced materials and their applications. Chemical Engineering Journal, 403, p.126162.
[29] EC EISMEA/GROW (2021) Advanced Technologies for Industries – Methodological Report. Indicator Framework and Data Calculations. ISBN 978-92-9202-952-4. doi:10.2826/911991.
[30] High Level Expert Group on Artificial Intelligence (AI HLEG) (2019a), A definition of AI: Main capabilities and disciplines, 8 April. In Samoili, S., López Cobo, M., Delipetrev, B., Martínez-Plumed, F., Gómez, E., and De Prato, G., AI Watch. Defining Artificial Intelligence 2.0. Towards an operational definition and taxonomy for the AI landscape, EUR 30873 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-42648-6, doi:10.2760/019901, JRC126426
[31] EC EISMEA/GROW (2021) Advanced Technologies for Industries – Methodological Report. Indicator Framework and Data Calculations. ISBN 978-92-9202-952-4. doi:10.2826/911991.

Augmented/Virtual Reality

Augmented/Virtual Reality is an immersive technology in which users can experience all of their human senses in a prominent virtual scene in a virtual world[32]. As such, the user is able to see his/her surroundings while also seeing the AR content -Virtual reality devices place end users into a completely new reality, obscuring the view of their existing reality.

Big Data

Big Data is an Information asset of High Volume, Velocity and Variety, that require specific Technology and Analytical Methods for its transformation into Value[33]. From a technology point of view, Big Data encompasses hardware and software that integrate, organise, manage, analyse and present data. Big Data technologies are new generation of technologies and architectures, designed to economically extract value from very large volumes of a wide variety of data, by enabling high-velocity capture, discovery and/or analysis[34].

Blockchain

Blockchain is part of the broader family of Distributed Ledger Technologies (DLTs). DLTs are particular types of databases in which data is recorded, shared and synchronised across a distributed network of computers or participants. Blockchain technologies are a particular type of DLT that employs cryptographic techniques to record and synchronize data in 'chains of blocks'. All types of Blockchain are DLTs but not all DLTs are Blockchains[35]. Blockchain entails three technologies, the blockchain itself, distributed ledger technologies, and smart contracts. Together they represent a fault-tolerant systems synchronising data through consensus mechanisms, able to verify - peer to peer - the correctness of such data through hash functions and values without central authorities, and executed upon some basic premises and protocols specified in digital form'[36].

Cloud computing

Cloud technologies offer a model of on-demand data storage and processing, both in centralised data centres and in distributed connected devices close to the user (at the 'edge' of the network). As cloud technologies are faster, cheaper and more flexible than conventional computing methods, many of our everyday services are based on the cloud, such as web-based email, entertainment systems, and public services including health and transportation. Whereas conventional cloud computing takes place in centralised data centres, edge computing data is processed in connected objects closer to the users. This allows for much faster operations and gives users more control over their data[37].

Biotechnology

Biotechnology is the application of biotechnology for the industrial processing and production of chemicals, materials and fuels. It relies on manipulating and growing bacteria, yeast, and filamentous fungi[38] to generate industrially useful products in a more efficient way (e.g. less energy use or less by-products), or generate substances and chemical building blocks with specific capabilities that conventional petrochemical processes cannot provide. There are many examples of such bio-based products already

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[32] Nee AYC, Ong SK, Chryssolouris G, Mourtzis D. Augmented reality applications in design and manufacturing. CIRP Ann - Manuf Technol 2012;61:657–79. https://doi.org/10.1016/j.cirp.2012.05.010

[33] De Mauro, A., Greco, M. and Grimaldi, M. (2016), "A formal definition of Big Data based on its essential features", Library Review, Vol. 65 No. 3, pp. 122-135. https://doi.org/10.1108/LR-06-2015-0061

[34] EC EISMEA/GROW (2021) Advanced Technologies for Industries – Methodological Report. Indicator Framework and Data Calculations. ISBN 978-92-9202-952-4. doi:10.2826/911991.

[35] Nascimento S., Pólvora A. , Sousa Lourenço J. (2018) #Blockchain4EU: Blockchain for Industrial Transformations, EUR 29215 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-85719-5 (pdf),978-92-79-85718-8 (print), doi:10.2760/204920 (online),10.2760/410134 (print), JRC111095

[36] Borbon-Galvez, et. Al. (2020) Secured by Blockchain. Deliverable WP1 (DR1_2020_01_20). Accessed 12/10/2022 https://www.liucbs.it/ricerca-applicata-e-advisory/progetti/secured-by-blockchain/

[37] EC (2022). Cloud and Edge Computing: a different way of using IT — Brochure. Accessed 12/10/2022. https://digital-strategy.ec.europa.eu/en/library/cloud-and-edge-computing-different-way-using-it-brochure#Future

[38] Nielsen, J., Tillegreen, C.B. and Petranovic, D., 2022. Innovation trends in industrial biotechnology. Trends in Biotechnology. https://doi.org/10.1016/j.tibtech.2022.03.007

on the market. The most mature applications are related to enzymes used in the food, feed and detergents sectors. More recent applications include the production of biochemicals and biopolymers from agricultural or forest wastes[39].

Internet of Things (IoT)

The Internet of Things is a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols, where physical and virtual 'things' have identities, physical attributes and virtual personalities and use intelligent interfaces and are seamlessly integrated into the information network[40]. The Internet of Things (IoT) refers to the network of smart, interconnected devices and services that are capable of sensing or even listening to requests. IoT is an aggregation of endpoints that are uniquely identifiable and that communicate bi-directionally over a network using some form of automated connectivity. Objects become interconnected, make themselves recognisable and acquire intelligence in the sense that they can communicate information about themselves and access information that has been provided by another source. The Internet of Things relies on networked sensors to remotely connect, track and manage products, systems and grids. The Industrial Internet of Things (IIoT) – a subset of the larger Internet of Things – focuses on the specialised requirements of industrial applications, such as manufacturing, oil and gas, and utilities. IIoT systems connect non-consumer devices, used by companies, governments, and utility providers in their service delivery[41].

Micro- and Nanoelectronics

Micro- and Nanoelectronics deal with semiconductor components and highly miniaturised electronic subsystems and their integration in larger products and systems. They include the fabrication, the design, the packaging and testing from nano-scale transistors to micro-scale systems integrating multiple functions on a chip[42].

Nanotechnology

Nanotechnology is the term given to those areas of science and engineering where phenomena that take place at dimensions in the nanometre scale are utilised in the design, characterisation, production and application of materials, structures, devices and systems. It has only been in the last quarter of a century that it has been possible to actively and intentionally modify molecules and structures within this size range. It is this control at the nanometre scale that distinguishes nanotechnology from other areas of technology[43]. Nanotechnology holds the promise of leading to the development of smart nano and micro devices and systems and to radical breakthroughs in vital fields such as healthcare, energy, environment and manufacturing.

Photonics

Photonics includes the sciences and techniques that generate, emit, detect, collect, transmit, modulate, amplify photon beams, from the terahertz band (min: 200 Gigahertz) to X-rays. Photonic based projects target the development of photonics core technologies as well as the development of whole products and systems based on photonic components. These photonic technologies are applied in multiple areas, among the most important ones are: personalised healthcare, industry 4.0, smart cities, homes, grid and digital infrastructures, secure digital society, environment and sustainability, frontier research

[39] EC EISMEA/GROW (2021) Advanced Technologies for Industries – Methodological Report. Indicator Framework and Data Calculations. ISBN 978-92-9202-952-4. doi:10.2826/911991.
[40] European Commission, Directorate-General for Communications Networks, Content and Technology, Cross-cutting business models for IoT : final report, Publications Office, 2018,
[41] EC EISMEA/GROW (2021) Advanced Technologies for Industries – Methodological Report. Indicator Framework and Data Calculations. ISBN 978-92-9202-952-4. doi:10.2826/911991.
[42] Idem.
[43] Allan J., Ferreri A., Grande S., Giannantonio R., Matteucci F., Technology Transfer in Nanotechnology, EUR 29686 EN, Publication Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-00671-8, doi:10.2760/183529, JRC115968

equipment, connected mobility, space and defence, smart farming and food production, knowledge transfer and smart learning, etc[44].

Robotics

Robotics, a domain of technology that produces programmable machines. It is a technology that encompasses the design, building, implementation and operation of robots. Robotics is often organised into three categories: 1) Application specific. This includes Robotics designed to conduct a specific task or series of tasks for commercial purposes. These robots may be stationary or mobile but are limited in function as defined by the intended application. 2) Multipurpose. Multipurpose robots are capable of performing a variety of functions and movements determined by a user that programs the robot for tasks, movement, range and other functions and that may change the effector based on the required task. These robots function autonomously within the parameters of their programming to conduct tasks for commercial applications and may be fixed, 'moveable' or mobile. 3) Cognitive. Cognitive robots are capable of decision making and reason, which allows them to function within a complex environment. These robots can learn and make decisions to support optimal function and performance and are designed for commercial applications. When measuring production and uptake of Robotics, industrial applications were taken into account[45].

Digital tech for Security/ Cybersecurity

'Cybersecurity' are activities necessary to protect network and information systems, the users of such systems, and other persons affected by cyber threats, whilst 'cybersecurity products and solutions' means ICT products, services or process with the specific purpose of protecting network and information systems, their users and affected persons from cyber threats[46]. Cybersecurity products are tools designed using a wide variety of technologies to enhance the security of an organisation's networking infrastructure — including computers, information systems, internet communications, networks, transactions, personal devices, mainframe and the cloud — as well as help provide advanced value-added services and capabilities. Cybersecurity products are utilised to provide confidentiality, integrity, privacy and assurance. Through the use of security applications, organisations are able to provide security management, access control, authentication, malware protection, encryption, data loss prevention (DLP), intrusion detection and prevention (IDP), vulnerability assessment (VA) and perimeter defense, among other capabilities[47].

Energy saving technologies

Energy-saving technologies at industrial level are systems, machinery, drives, thermal systems, combustion or electrical systems, or industrial design features of the production processes or operations that increase the energy efficiency of buildings, transport and production processes[48].

Renewable energy technologies

Renewable energy technologies are converters of Earth's ecosystem energy into energy products. Examples of energy technologies included are biomass, wind, solar, hydropower, geothermal, marine energies converters. Energy products include electricity, heat,

[44] Photonics21 (2017) Photonics – a critical Key Enabling Technology for Europe. Access 13/10/2022.
[45] EC EISMEA/GROW (2021) Advanced Technologies for Industries – Methodological Report. Indicator Framework and Data Calculations. ISBN 978-92-9202-952-4. doi:10.2826/911991.
[46] European Commission (2019). Proposal for a Regulation of the European Parliament and of the Council Establishing the European Cybersecurity Industrial, Technology and Research Competence Centre and the Network of National Coordination Centres, COM(2018) 630 Final, 9 December 2018c.
[47] EC EISMEA/GROW (2021) Advanced Technologies for Industries – Methodological Report. Indicator Framework and Data Calculations. ISBN 978-92-9202-952-4. doi:10.2826/911991.
[48] Löschel, A., Lutz, B.J. and Massier, P., 2017. Credit constraints, energy management practices, and investments in energy saving technologies: German manufacturing in close-up. ZEW, Zentrum für Europäische Wirtschaftsforschung GmbH.

hydrocarbons, steam, methanol, bio-oils, biodiesel, charcoal, cold, light, movement (power), ventilation, etc. [49]

Clean production technologies

The UN[50] defines clean production as the continuous application of an integrated preventive environmental strategy applied to processes, products, and services to increase overall efficiency and reduce risks to humans and the environment. Clean production technologies create products with less environmental impact and focus on the reduction of the use of natural resources. In this project, technologies that aim at reducing the creation of waste, or the use of water and raw materials have been taken into account.

Recycling and waste management technologies

Recycling technology means a specific combination of physical and chemical concepts, principles, and practices to recycle a waste stream of a certain type and collected in a certain way into recycled plastic materials and articles of a specific type and with a specific intended use and includes a decontamination technology[51].

Circular business models

As defined by the OECD (2019)[52] circular business models serve to reduce the extraction and use of natural resources and the generation of industrial and consumer wastes. They represent the key activities required to transition to a more resource efficient and circular economy. Key circular business models that are monitored in this project include:

- Remanufacturing
- Renting, leasing and related service models
- Repair and maintenance services
- Resell, reuse
- Circular design (products that can be disassembled and recycled)
- Design for durability (products that can last longer)

[49] Turkenburg, et. Al. (2015) Renewable Energy Technologies. In UNPD, UNDESA, and WEC. World Energy Assessment. Energy and the challenges of sustainability. UNPD. Accessed 14/10/2022
[50] https://www.unep.org/resources/report/environmental-agreements-and-cleaner-production
[51] https://www.lawinsider.com/dictionary/recycling-technology
[52] OECD (2019). Business Models for the Circular Economy Opportunities and Challenges from a Policy Perspective

Appendix B: Industrial ecosystem coverage by source

This appendix includes tables indicating the coverage of each industrial ecosystem by data source (i.e. Patent, Crunchbase/Net Zero Insights, LinkedIn, CORDA, UNComtrade, SkillsOvate).

Figure 5: Crunchbase & Net Zero Insights data

Industrial Ecosystem	NACE rev2	Description	Scope
Aerospace & Defence	C25	Manufacture of fabricated metal products, except machinery and equipment	
	C26	Manufacture of computer, electronic and optical products	x
	C27*	Manufacture of electrical equipment	
	C30	Manufacture of other transport equipment	x
	C33	Repair and installation of machinery and equipment	
	H51	Air transport	x
	H52*	Warehousing and support activities for transportation	
	J61	Telecommunications	x
	N80	Security and investigation activities	x
Agri-food	A	Agriculture, forestry and fishing	x
	C10	Manufacture of food products	x
	C11	Manufacture of beverages	x
	C12	Manufacture of tobacco products	x
Construction	C31	Manufacture of furniture	
	F	Construction	x
	M71	Architectural and engineering activities; technical testing and analysis	x
	N81	Services to buildings and landscape activities	x
Cultural and Creative Industries	C18	Printing and reproduction of recorded media	x
	C32	Other manufacturing	
	G47*	Retail trade, except of motor vehicles and motorcycles	
	J58	Publishing activities	x
	J59	Motion picture, video and television programme production, sound recording and music publishing activities	x
	J60	Programming and broadcasting activities	x
	J62_63	Computer programming, consultancy and related activities;	x
	M71	Architectural and engineering activities; technical testing and analysis	x
	M73	Advertising and market research	
	M74_M75	Other professional, scientific and technical activities and veterinary activities	x
	N77	Rental and leasing activities	
	P85	Education	
	R90-R92	Creative, arts and entertainment activities; libraries, archives, museums and other cultural activities; gambling and betting activities	x
	S94	Activities of membership organisations	
	S95	Repair of computers and personal and household goods	
Digital	C26*	Manufacture of computer, electronic and optical products	
	J58	Publishing activities	
	J61	Telecommunications	
	J62	Computer programming, consultancy and related activities	
	J63	Information service activities	
	S95	Repair of computers and personal and household goods	
Electronics	C26	Manufacture of computer, electronic and optical products	x
	C28	Manufacture of machinery and equipment n.e.c.	

Industrial Ecosystem	NACE rev2	Description	Scope
Energy - Renewables	C27*	Manufacture of electrical equipment	
	D35	Electricity, gas, steam and air conditioning supply	x
Energy Intensive Industries	C16		x
	C17	Manufacture of paper and paper products	x
	C19	Manufacture of coke and refined petroleum products	
	C20	Manufacture of chemicals and chemical products	x
	C22	Manufacture of rubber and plastic products	x
	C23	Manufacture of other non-metallic mineral products	x
	C24	Manufacture of basic metals	x
Health	C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	x
	C33	Manufacture of medical and surgical equipment and orthopaedic appliances	x
	C32	Other manufacturing	
	Q86	Human health activities	x
	Q87_Q88	Residential care activities and social work activities without accommodation	x
Mobility - Transport - Automotive	C27	Manufacture of electrical equipment	
	C29	Manufacture of motor vehicles, trailers and semi-trailers	x
	C30	Manufacture of other transport equipment	x
	G45	Wholesale and retail trade and repair of motor vehicles and motorcycles	
	H49	Land transport and transport via pipelines	x
	H50	Water transport	
	H52	Warehousing and support activities for transportation	
Proximity, Social Economy and Civil Security	G47*	Retail trade, except of motor vehicles and motorcycles	
	I	Accommodation and food service activities	
	L	Real estate activities	
	N81	Services to buildings and landscape activities	
	N82	Office administrative, office support and other business support activities	
	Q87_Q88	Residential care activities and social work activities without accommodation	
	S95	Repair of computers and personal and household goods	
	S96	Other personal service activities	
	T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	
Retail	G46	Wholesale trade, except of motor vehicles and motorcycles	x
	G47	Retail trade, except of motor vehicles and motorcycles	x
	H53	Postal and courier activities	x
Textile	C13	Manufacture of textiles	x
	C14	Manufacture of wearing apparel	x
	C15	Manufacture of leather and related products	x
Tourism	H49	Land transport and transport via pipeline	
	H50	Water transport	
	H51	Air transport	x
	I	Accommodation and food service activities	x
Tourism	N79	Travel agency, tour operator and other reservation service and related activitieS	x
	N82	Office administrative, office support and other business support activities	
	R90-R92	Creative, arts and entertainment activities; libraries, archives, museums and other cultural activities; gambling and betting activities	x
	R93	Sports activities and amusement and recreation activities	x

Source: Consortium

Figure 6: Tags and keywords matched by industrial ecosystem in Crunchbase and Net Zero Insights

Industrial Ecosystem	Industry tags (Crunchbase and Net Zero Insights) and keywords
Aerospace & Defence	Industry tags Crunchbase: Aerospace, Space Travel, Satellite communication, Military, National Security, Geospatial, GPS, Location Based Services, Mapping Services, Navigation, Drones Keywords: Aerospace, Space Travel, Satellite communication, Military, National Security, Drones, Geospatial, GPS, Location Based Services, Mapping Services, Navigation, defence, aeronautic, navigation, air traffic, space traffic, earth observation, Launchers, Space Industry, Defence Industry, Aeronautics, Chemical Biological Radiological Nuclear, Unmanned Air Systems, Space Situational Awareness, Space Command and Control, Geostationary Equatorial Orbit, Low Earth Orbit, ballistic missile, Maritime surveillance, radars, strike capabilities, Ground combat, Air combat, Defence capabilities, Defence technologies, space intelligence, Space Assets, Avionics, spacecraft, orbit sensors, EGNOS, Copernicus & Galileo, Geostationary Orbit, Orbit Data Centres, flight management, airframe, airline operations, hybrid-elecric turboprop.
Agri-Food	Industry tags Crunchbase: Agriculture and Farming: Agriculture, AgTech, Animal Feed, Aquaculture, Farming, Horticulture, Hydroponics, Livestock, Food and Beverage: Bakery, Brewing, Catering, Coffee, Confectionery, Craft Beer, Dietary Supplements, Distillery, Farmers Market, Food and Beverage, Food Delivery, Food Processing, Food Trucks, Fruit, Grocery, Nutrition, Organic Food, Seafood, Snack Food, Tea, Tobacco, Wine And Spirits, Winery, Restaurants Industry tags Net Zero insights: Precision Agriculture, Food and Beverage, Vertical Farming, Agriculture
Construction	Industry tags Crunchbase: Architecture, Building Maintenance, Construction, Green Building, Smart Building, Civil Engineering, facility management, home renovation, interior design, landscaping, home improvement, home services, janitorial service, electrical distribution Industry tags Net Zero insights: Construction, Green building, Built environment
Creative & Cultural Industries	Industry tags Crunchbase: Architecture, Advertising, Video Games, Music, Internet radio, News, Journalism, Printing, Publishing, Audiobooks, E-books, Photography, Performing arts, Theatre, Arts, Design, Film, Film production, Film distribution, Museums and historical sites, Independent music, Music label, Music streaming, Music venues, Musical instruments, Gamification, TV, TV production
Digital	Industry tags Crunchbase: Artificial Intelligence, Big Data, Internet of Things, Robotics, Blockchain, Augmented Reality, Virtual Reality, Cloud technologies
Electronics	Industry tags Crunchbase: Semiconductor, Electronics, Electronic design automation Industry tags Net Zero Insights: Sensor Keywords: Semiconductor, semiconductor material, organic electronic, biobased electronic, print electronic, nanochip, microchip, chip tech, silicon chip, Lidar,
Energy Intensive Industries	Industry tags Crunchbase: Chemicals, Paper Manufacturing, Plastics and Rubber Manufacturing, Mineral, Mining, Mining Technology, Wood Processing, Building material Industry tags Net Zero Insights: Chemical, Steel, Manufacture of Iron and steel Keywords: Steel, Iron, Alluminium, Metal
Healthcare	Industry tags Crunchbase: Health Care, Pharmaceuticals, Medical devices, Alternative Medicine, Assisted Living, Assistive Technology, Biopharma, Clinical Trials, Cosmetic Surgery, Dental, Diabetes, Dietary Supplements, Electronic Health Record (EHR), Emergency Medicine, Fertility, First Aid, Genetics, Health Care, Health Diagnostics, Home Health Care, Hospital, Medical, Medical Device, mHealth, Nursing and Residential Care, Nutraceutical, Outpatient Care, Personal Health, Pharmaceutical, Psychology, Rehabilitation, Therapeutics.

Industrial Ecosystem	Industry tags (Crunchbase and Net Zero Insights) and keywords
Mobility, Transport & Automotive	Industry tags Crunchbase: Automotive, Autonomous Vehicles, Car Sharing, Electric Vehicle, Recreational Vehicles, Ride Sharing, Transportation
Proximity & Social Economy	Industry tags Crunchbase: Green consumer goods, Charity, collaborative consumption, homeless shelter, non profit, Sharing economy, social bookmarking, social impact, social recruiting, Recycling, Pollution control, Social, Social Entrepreneurship, Social Shopping. Industry tags Net Zero Insights: Electric vehicle. Autonomous vehicle, Shared mobility, Mobility
Renewable Energy	Industry tags Crunchbase: Renewable Energy, Solar, Wind Energy, Clean Energy, Energy Storage, Energy Management, Biofuel, Biomass Energy, Cleantech, Industry tags Net Zero Insights: Maritime, Fuels, Electricity, Heating, Bioeconomy, Sustainable Aviation Fuels (SAFs), Ocean energy, Offshore energy
Retail	Industry tags Crunchbase: Retail, Retail Technology, E-commerce, E-commerce Platforms, Marketplace, Shopping, Point of Sale, Personalisation, Wholesale, Warehousing and Mobile Payments (including retail, customer, business and payment within their description) Keywords: B2C, B2B, Clothing, commerce platform, e-commerce, ecommerce, fashion, food, furniture, grocer, Marketplace, online payment, online retailer, pay later, payment enabler, recommerce, retail, shopping, supermarket
Textiles	Industry tags Crunchbase: Textiles, Fashion, Lingerie, Shoes Industry tags Net Zero Insights: Textile and Fashion, Logistics Keywords: Textile, Apparel, Clothing, Cotton, yarn, fabric, leather, linens, garment, Fiber, Biofiber, Fiber, weaving, bioopolymer, dyeing, filament, polyester, knitting, enzymes
Tourism	Industry tags Crunchbase: Hotel, Travel Accommodations, Hospitality, Vacation Rental, Restaurants Travel arrangement and reservation services Travel Agency, Adventure Travel, Business Travel, Hospitality, Tour Operator, Sports, Amusement Park Museums and Historical Sites, Parks, Resorts, Casino Public Transportation, Railroad, Marine Transportation, Air Transportation Industry tags Net Zero Insights: sustainable aviation, food waste + keywords Keywords: hospitality provider, hospitality industry, hotel, vacation rental, Business travel, tourism, museum, accommodation marketplace, casino, travel agency, travel agent, tour operator, Resorts, Adventure travel, travel industry, Amusement Park, theme park, air transportation, aviation company and airline, Restaurant, food service, bar, food delivery.

Source: Consortium

Figure 7: LinkedIn industry categories used per industrial ecosystem

Industrial Ecosystem	NACE_rev 2	NACE_rev2_labels	LinkedIn
Aerospace & Defence	C25	Manufacture of fabricated metal products, except machinery and equipment	Aviation and Aerospace, Defense and Space
Aerospace & Defence	C26	Manufacture of computer, electronic and optical products	Aviation and Aerospace, Defense and Space
Aerospace & Defence	C27*	Manufacture of electrical equipment	Aviation and Aerospace, Defense and Space
Aerospace & Defence	C30	Manufacture of other transport equipment	Aviation and Aerospace, Defense and Space
Aerospace & Defence	C33.1	Repair and installation of machinery and equipment	
Aerospace & Defence	H51	Air transport	Aviation and Aerospace, Defense and Space
Aerospace & Defence	H52*	Warehousing and support activities for transportation	
Aerospace & Defence	J61	Telecommunications	
Aerospace & Defence	N80	Security and investigation activities	Defense and Space
Agri-food	A	Agriculture, forestry and fishing	Farming, Ranching, Fishery, Dairy
Agri-food	C10	Manufacture of food products	Food & Beverages, Food Production
Agri-food	C11	Manufacture of beverages	Food & Beverages, Wine & Spirits
Agri-food	C12	Manufacture of tobacco products	
Construction	C31	Manufacture of furniture	
Construction	F	Construction	Construction
Construction	M71	Architectural and engineering activities; technical testing and analysis	Architecture & Planning,
Construction	N81	Services to buildings and landscape activities	Civil engineering
Cultural and Creative Industries	C18	Printing and reproduction of recorded media	Music, Design, Computer Games
Cultural and Creative Industries	C32	Other manufacturing	

Industrial Ecosystem	NACE_rev 2	NACE_rev2_labels	LinkedIn
Cultural and Creative Industries	G47*	Retail trade, except of motor vehicles and motorcycles	
Cultural and Creative Industries	J58	Publishing activities	Publishing, Writing & Editing, Online Media, Newspaper
Cultural and Creative Industries	J59	Motion picture, video and television programme production, sound recording and music publishing activities	Motion Pictures & Film
Cultural and Creative Industries	J60	Programming and broadcasting activities	Broadcast Media,
Cultural and Creative Industries	J62_63	Computer programming, consultancy and related activities;	
Cultural and Creative Industries	M71	Architectural and engineering activities; technical testing and analysis	Architecture & Planning,
Cultural and Creative Industries	M73	Advertising and market research	Marketing & Advertising,
Cultural and Creative Industries	M74_M75	Other professional, scientific and technical activities and veterinary activities	
Cultural and Creative Industries	N77	Rental and leasing activities	
Cultural and Creative Industries	P85	Education	
Cultural and Creative Industries	R90-R92	Creative, arts and entertainment activities; libraries, archives, museums and other cultural activities; gambling and betting activities	Museums, Performing Arts, Fine Art, Arts & Crafts
Cultural and Creative Industries	S94	Activities of membership organisations	
Cultural and Creative Industries	S95	Repair of computers and personal and household goods	
Digital	C26*	Manufacture of computer, electronic and optical products	
Digital	J58	Publishing activities	
Digital	J61	Telecommunications	
Digital	J62	Computer programming, consultancy and related activities	

Industrial Ecosystem	NACE_rev 2	NACE_rev2_labels	LinkedIn
Digital	J63	Information service activities	
Digital	S95	Repair of computers and personal and household goods	
Electronics	C26	Manufacture of computer, electronic and optical products	Electronics, Semiconductors
Electronics	C28	Manufacture of machinery and equipment n.e.c.	
Energy - Renewables	C27*	Manufacture of electrical equipment	
Energy - Renewables	D35	Electricity, gas, steam and air conditioning supply	
Energy Intensive Industries	C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	Paper & Forest Products
Energy Intensive Industries	C17	Manufacture of paper and paper products	Paper & Forest Products
Energy Intensive Industries	C19	Manufacture of coke and refined petroleum products	
Energy Intensive Industries	C20	Manufacture of chemicals and chemical products	Chemicals
Energy Intensive Industries	C22	Manufacture of rubber and plastic products	Plastics
Energy Intensive Industries	C23	Manufacture of other non-metallic mineral products	Mining & Metals, Glass, Ceramics & Concrete
Energy Intensive Industries	C24	Manufacture of basic metals	Mining & Metals
Health	C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	Pharmaceuticals
Health	C33	Manufacture of medical and surgical equipment and orthopaedic appliances	Medical devices
Health	C32	Other manufacturing	
Health	Q86	Human health activities	Hospital and Healthcare
Health	Q87_Q88	Residential care activities and social work activities without accommodation	Hospital and Healthcare

Industrial Ecosystem	NACE_rev 2	NACE_rev2_labels	LinkedIn
Mobility - Transport - Automotive	C27	Manufacture of electrical equipment	
Mobility - Transport - Automotive	C29	Manufacture of motor vehicles, trailers and semi-trailers	Automotive
Mobility - Transport - Automotive	C30	Manufacture of other transport equipment	Shipbuilding
Mobility - Transport - Automotive	G45	Wholesale and retail trade and repair of motor vehicles and motorcycles	
Mobility - Transport - Automotive	H49	Land transport and transport via pipelines	Transportation/Trucking/Railroad
Mobility - Transport - Automotive	H50	Water transport	Transportation/Trucking/Railroad
Mobility - Transport - Automotive	H52	Warehousing and support activities for transportation	
Proximity, Social Economy and Civil Security	G47*	Retail trade, except of motor vehicles and motorcycles	
Proximity, Social Economy and Civil Security	I	Accommodation and food service activities	
Proximity, Social Economy and Civil Security	L	Real estate activities	
Proximity, Social Economy and Civil Security	N81	Services to buildings and landscape activities	
Proximity, Social Economy and Civil Security	N82	Office administrative, office support and other business support activities	
Proximity, Social Economy and Civil Security	Q87_Q88	Residential care activities and social work activities without accommodation	Civic & Social Organisation, Environmental Services, Non-profit Organisation Management

Industrial Ecosystem	NACE_rev 2	NACE_rev2_labels	LinkedIn
Proximity, Social Economy and Civil Security	S95	Repair of computers and personal and household goods	
Proximity, Social Economy and Civil Security	S96	Other personal service activities	
Proximity, Social Economy and Civil Security	T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	
Retail	G46	Wholesale trade, except of motor vehicles and motorcycles	Wholesale
Retail	G47	Retail trade, except of motor vehicles and motorcycles	Retail
Retail	H53	Postal and courier activities	
Textile	C13	Manufacture of textiles	Textiles
Textile	C14	Manufacture of wearing apparel	Apparel & Fashion
Textile	C15	Manufacture of leather and related products	
Tourism	H49	Land transport and transport via pipeline	Transportation
Tourism	H50	Water transport	Transportation
Tourism	H51	Air transport	Transportation
Tourism	I	Accommodation and food service activities	Hospitality, Restaurants,
Tourism	N79	Travel agency, tour operator and other reservation service and related activitieS	Leisure, Travel & Tourism,
Tourism	N82	Office administrative, office support and other business support activities	
Tourism	R90-R92	Creative, arts and entertainment activities; libraries, archives, museums and other cultural activities; gambling and betting activities	Museums & Institutions, Gambling & Casinos, Leisure, Travel & Tourism,
Tourism	R93	Sports activities and amusement and recreation activities	Recreational Facilities & Services

Source: Consortium

Keywords used as part of the LinkedIn analysis

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 Centres, Oracle Database, SAP Solution Architecture Data Entry, Data Management, Data Mapping, Web Applications, GIS Applications, Oracle Applications, Visual Basic for Applications (VBA), Computer Hardware, Computer Maintenance, Computer Network Operations, Computer Networking, Computer Graphics, Online Communications, Social Media Marketing, Digital Direct Marketing, Digital Illustration, Digital Video, Digital Photography, Xero, GPS Applications, GPS Devices, GPS Tracking, GPS Navigation, Microsoft Power Apps, Social Networking Apps, Google Apps Script, Social Media, E-Commerce, Data Intelligence, Online Platforms, Mobile Payments

Figure 8: Keywords used as part of the Corda data analysis

Industrial ecosystem	Keywords
Tourism	vacation, hospitality, air transport & tourism, restaurants, wheelchair access*, disabled guest*, culture, transport & tourism, tourism
Aerospace & Defence	aerospace, military, defence, aeronautic, navigation, air traffic, space traffic, earth observation, Launchers, Space Industry, Defence Industry, Aeronautics, Chemical Biological Radiological Nuclear, Unmanned Air Systems, Space Situational Awareness, Space Command and Control, Geostationary Equatorial Orbit, Low Earth Orbit, ballistic missile, Maritime surveillance, radars, strike capabilities, Ground combat, Air combat, Defence capabilities, Defence technologies, space intelligence, Space Assets, Avionics, spacecraft, orbit sensors, EGNOS, Copernicus & Galileo, Geostationary Orbit, Orbit Data Centres, flight management, airframe, airline operations, hybrid-elecric turboprop
Agri-food	fisheries, food safety, animal husbandry, plant protection, fruit growing, nutrition, vegetable growing, horticulture, agriculture, legumes, cereals, animal feed, viticulture, food technology, food packaging, oilseeds
Construction	architecture, building, building maintenance, construction, green building, smart building, civil engineering, facility management, home renovation, interior design, landscaping, home improvement, home services, janitorial service, electrical distribution
Cultural and Creative Industries	video games, Music cinematography, Journalism, arts, radio and television
Electronics	Semicondutivity, electrical engineering, electromagnetism and electronics, lab on a chip, organ on a chip
Energy - Renewables	Renewable Energy, Solar power, solar energy, Wind power, electric batteries, electric power, fuel cells, hydrogen energy, electric energy, Biofuel, Biomass, photovolatics
Energy Intensive Industries	Chemicals, Paper Manufacturing, Plastics and Rubber Manufacturing, Mineral, Mining, Mining Technology, Wood Processing, Building material, Mining and mineral processing, metalurgy, ceramics, woodworking, industrial crops
Health	Health care services, vaccines, virology, mortality, infectious disease, immunisation, organ on a chip, public health, cancer, nanomedicine, surgery, alzheimer, drug discovery, disease, physiotherapy, Pharmaceutical, personalized medicine, eHealth, diabetes, allergy, radiology, parkinsons, stroke, surgical procedures, orthopaedics, fetal medicine, hematology, cardiovascular diseases, pharmacokinetics, toxicology, antibiotic resistance, bone, muscular, glaucoma
Mobility - Transport - Automotive	Public Transport, intelligent transport systems, autonomous vehicles, electric vehicles, freight transport, automotice engineering
Proximity, Social Economy and Civil Security	n.a.
Retail	n.a.
Textile	textile, apparel, clothing, cotton, yarn, leather, textile machinery, shoe, embroidery, Fiber, Biofiber, weaving, polymer, biopolymer, dyeing, filament, polyester, knitting,

Industrial ecosystem	Keywords
	enzymes, textile, apparel, clothing, cotton, yarn, leather, textile machinery, shoe, embroidery

Source: Consortium

Notes: Blank cells represent industrial ecosystems for which the analysis was not conducted.

Figure 9: Online Job Advertisements based on SkillsOvate data

Industrial Ecosystem	NACE_rev2	Description	Scope
Tourism	H49	Land transport and transport via pipeline	
Tourism	H50	Water transport	
Tourism	H51	Air transport	
Tourism	I	Accommodation and food service activities	x
Tourism	N79	Travel agency, tour operator and other reservation service and related activities	x
Tourism	N82	Office administrative, office support and other business support activities	
Tourism	R90-R92	Creative, arts and entertainment activities; libraries, archives, museums and other cultural activities; gambling and betting activities	x
Tourism	R93	Sports activities and amusement and recreation activities	x
Aerospace & Defence	C25	Manufacture of fabricated metal products, except machinery and equipment	
Aerospace & Defence	C26_ad	Manufacture of computer, electronic and optical products	x
Aerospace & Defence	C27*	Manufacture of electrical equipment	x
Aerospace & Defence	C30	Manufacture of other transport equipment	x
Aerospace & Defence	C33.1	Repair and installation of machinery and equipment	
Aerospace & Defence	H51	Air transport	
Aerospace & Defence	H52*	Warehousing and support activities for transportation	
Aerospace & Defence	J61	Telecommunications	
Aerospace & Defence	N80	Security and investigation activities	x
Agri-food	A	Agriculture, forestry and fishing	x
Agri-food	C10	Manufacture of food products	x
Agri-food	C11	Manufacture of beverages	x
Agri-food	C12	Manufacture of tobacco products	x
Construction	C31	Manufacture of furniture	x

Industrial Ecosystem	NACE_rev2	Description	Scope
Construction	F	Construction	x
Construction	M71	Architectural and engineering activities; technical testing and analysis	x
Construction	N81	Services to buildings and landscape activities	x
Cultural and Creative Industries	C18	Printing and reproduction of recorded media	x
Cultural and Creative Industries	C32	Other manufacturing	
Cultural and Creative Industries	G47*	Retail trade, except of motor vehicles and motorcycles	
Cultural and Creative Industries	J58	Publishing activities	x
Cultural and Creative Industries	J59	Motion picture, video and television programme production, sound recording and music publishing activities	x
Cultural and Creative Industries	J60	Programming and broadcasting activities	x
Cultural and Creative Industries	J62_63	Computer programming, consultancy and related activities;	
Cultural and Creative Industries	M71	Architectural and engineering activities; technical testing and analysis	
Cultural and Creative Industries	M73	Advertising and market research	x
Cultural and Creative Industries	M74_M75	Other professional, scientific and technical activities and veterinary activities	
Cultural and Creative Industries	N77	Rental and leasing activities	
Cultural and Creative Industries	P85	Education	
Cultural and Creative Industries	R90-R92	Creative, arts and entertainment activities; libraries, archives, museums and other cultural activities; gambling and betting activities	x
Cultural and Creative Industries	S94	Activities of membership organisations	
Cultural and Creative Industries	S95	Repair of computers and personal and household goods	
Digital	C26*	Manufacture of computer, electronic and optical products	x
Digital	J58	Publishing activities	x
Digital	J61	Telecommunications	x

Industrial Ecosystem	NACE_rev2	Description	Scope
Digital	J62	Computer programming, consultancy and related activities	x
Digital	J63	Information service activities	x
Digital	S95	Repair of computers and personal and household goods	x
Electronics	C26	Manufacture of computer, electronic and optical products	x
Electronics	C28	Manufacture of machinery and equipment n.e.c.	
Energy - Renewables	C27*	Manufacture of electrical equipment	x
Energy - Renewables	D35	Electricity, gas, steam and air conditioning supply	x
Energy Intensive Industries	C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	x
Energy Intensive Industries	C17	Manufacture of paper and paper products	x
Energy Intensive Industries	C19	Manufacture of coke and refined petroleum products	x
Energy Intensive Industries	C20	Manufacture of chemicals and chemical products	x
Energy Intensive Industries	C22	Manufacture of rubber and plastic products	x
Energy Intensive Industries	C23	Manufacture of other non-metallic mineral products	x
Energy Intensive Industries	C24	Manufacture of basic metals	x
Health	C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	x
Health	C33	Manufacture of medical and surgical equipment and orthopaedic appliances	x
Health	C32	Other manufacturing	
Health	Q86	Human health activities	x
Health	Q87_Q88	Residential care activities and social work activities without accommodation	x
Mobility - Transport - Automotive	C27	Manufacture of electrical equipment	
Mobility - Transport - Automotive	C29	Manufacture of motor vehicles, trailers and semi-trailers	x

Industrial Ecosystem	NACE_rev2	Description	Scope
Mobility - Transport - Automotive	C30	Manufacture of other transport equipment	x
Mobility - Transport - Automotive	G45	Wholesale and retail trade and repair of motor vehicles and motorcycles	x
Mobility - Transport - Automotive	H49	Land transport and transport via pipelines	x
Mobility - Transport - Automotive	H50	Water transport	x
Mobility - Transport - Automotive	H52	Warehousing and support activities for transportation	
Proximity, Social Economy and Civil Security	G47*	Retail trade, except of motor vehicles and motorcycles	
Proximity, Social Economy and Civil Security	I	Accommodation and food service activities	
Proximity, Social Economy and Civil Security	L	Real estate activities	
Proximity, Social Economy and Civil Security	N81	Services to buildings and landscape activities	
Proximity, Social Economy and Civil Security	N82	Office administrative, office support and other business support activities	
Proximity, Social Economy and Civil Security	Q87_Q88	Residential care activities and social work activities without accommodation	x
Proximity, Social Economy and Civil Security	S95	Repair of computers and personal and household goods	x
Proximity, Social Economy and Civil Security	S96	Other personal service activities	x
Proximity, Social Economy and Civil Security	T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	x
Retail	G46	Wholesale trade, except of motor vehicles and motorcycles	x
Retail	G47	Retail trade, except of motor vehicles and motorcycles	x
Retail	H53	Postal and courier activities	x
Textile	C13	Manufacture of textiles	x
Textile	C14	Manufacture of wearing apparel	x

Industrial Ecosystem	NACE_rev2	Description	Scope
Textile	C15	Manufacture of leather and related products	x

Source: Consortium

Notes: Blank cells represent divisions of industrial ecosystems which were excluded from the analysis for ease of interpretation in the context of the industrial ecosystem report.

Figure 10: Industrial ecosystem coverage – Survey

Industrial ecosystem	NACE_rev2	Description	Scope
Tourism	H49	Land transport and transport via pipeline	
Tourism	H50	Water transport	
Tourism	H51	Air transport	
Tourism	I	Accommodation and food service activities	x
Tourism	N79	Travel agency, tour operator and other reservation service and related activitieS	x
Tourism	N82	Office administrative, office support and other business support activities	
Tourism	R93	Sports activities and amusement and recreation activities	x
Aerospace & Defence	C25	Manufacture of fabricated metal products, except machinery and equipment	
Aerospace & Defence	C26	Manufacture of computer, electronic and optical products	x
Aerospace & Defence	C27*	Manufacture of electrical equipment	
Aerospace & Defence	C30	Manufacture of other transport equipment	x
Aerospace & Defence	C33	Repair and installation of machinery and equipment	
Aerospace & Defence	H51	Air transport	x
Aerospace & Defence	H52*	Warehousing and support activities for transportation	
Aerospace & Defence	J61	Telecommunications	x
Aerospace & Defence	N80	Security and investigation activities	
Agri-food	A	Agriculture, forestry and fishing	x
Agri-food	C10	Manufacture of food products	x
Agri-food	C11	Manufacture of beverages	x
Agri-food	C12	Manufacture of tobacco products	
Construction	F	Construction	x

Industrial ecosystem	NACE_rev2	Description	Scope
Construction	M71	Architectural and engineering activities; technical testing and analysis	x
Construction	N81	Services to buildings and landscape activities	x
Cultural and Creative Industries	C18	Printing and reproduction of recorded media	x
Cultural and Creative Industries	C18	Printing and reproduction of recorded media	
Cultural and Creative Industries	C32	Other manufacturing	
Cultural and Creative Industries	G47*	Retail trade, except of motor vehicles and motorcycles	
Cultural and Creative Industries	J58	Publishing activities	x
Cultural and Creative Industries	J59	Motion picture, video and television programme production, sound recording and music publishing activities	x
Cultural and Creative Industries	J60	Programming and broadcasting activities	
Cultural and Creative Industries	J62_63	Computer programming, consultancy and related activities;	
Cultural and Creative Industries	M71	Architectural and engineering activities; technical testing and analysis	
Cultural and Creative Industries	M73	Advertising and market research	x
Cultural and Creative Industries	M74_M75	Other professional, scientific and technical activities and veterinary activities	
Cultural and Creative Industries	N77	Rental and leasing activities	
Cultural and Creative Industries	P85	Education	
Cultural and Creative Industries	R90-R92	Creative, arts and entertainment activities; libraries, archives, museums and other cultural activities; gambling and betting activities	x
Cultural and Creative Industries	S94	Activities of membership organisations	

Industrial ecosystem	NACE_rev2	Description	Scope
Cultural and Creative Industries	S95	Repair of computers and personal and household goods	
Electronics	C26	Manufacture of computer, electronic and optical products	x
Electronics	C28	Manufacture of machinery and equipment n.e.c.	
Energy Intensive Industries	C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	x
Energy Intensive Industries	C17	Manufacture of paper and paper products	x
Energy Intensive Industries	C19	Manufacture of coke and refined petroleum products	x
Energy Intensive Industries	C20	Manufacture of chemicals and chemical products	x
Energy Intensive Industries	C22	Manufacture of rubber and plastic products	x
Energy Intensive Industries	C23	Manufacture of other non-metallic mineral products	x
Energy Intensive Industries	C24	Manufacture of basic metals	x
Health	C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	x
Health	C33	Manufacture of medical and surgical equipment and orthopaedic appliances	x
Health	C32	Other manufacturing	
Health	Q86	Human health activities	
Health	Q87_Q88	Residential care activities and social work activities without accommodation	
Mobility - Transport - Automotive	C27	Manufacture of electrical equipment	x
Mobility - Transport - Automotive	C29	Manufacture of motor vehicles, trailers and semi-trailers	x
Mobility - Transport - Automotive	C30	Manufacture of other transport equipment	x
Mobility - Transport - Automotive	G45	Wholesale and retail trade and repair of motor vehicles and motorcycles	

Industrial ecosystem	NACE_rev2	Description	Scope
Mobility - Transport - Automotive	H49	Land transport and transport via pipelines	x
Mobility - Transport - Automotive	H50	Water transport	
Mobility - Transport - Automotive	H52	Warehousing and support activities for transportation	
Proximity, Social Economy and Civil Security	G47*	Retail trade, except of motor vehicles and motorcycles	
Proximity, Social Economy and Civil Security	I	Accommodation and food service activities	
Proximity, Social Economy and Civil Security	L	Real estate activities	
Proximity, Social Economy and Civil Security	N81	Services to buildings and landscape activities	
Proximity, Social Economy and Civil Security	N82	Office administrative, office support and other business support activities	
Proximity, Social Economy and Civil Security	Q87_Q88	Residential care activities and social work activities without accommodation	x
Proximity, Social Economy and Civil Security	S95	Repair of computers and personal and household goods	
Proximity, Social Economy and Civil Security	S96	Other personal service activities	
Proximity, Social Economy and Civil Security	T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	
Proximity, Social Economy and Civil Security	G47*	Retail trade, except of motor vehicles and motorcycles	
Proximity, Social Economy and Civil Security	I	Accommodation and food service activities	
Retail	G46	Wholesale trade, except of motor vehicles and motorcycles	x
Retail	G47	Retail trade, except of motor vehicles and motorcycles	x
Textile	C13	Manufacture of textiles	x

Industrial ecosystem	NACE_rev2	Description	Scope
Textile	C14	Manufacture of wearing apparel	x
Textile	C15	Manufacture of leather and related products	x

Source: Consortium

Notes: Blank cells represent divisions of industrial ecosystems which were excluded from the analysis to avoid

Appendix C: Technology coverage by patent, prodcom and trade data

Figure 11: Technologies – Patents

Technology	Approach
Green transition	
Advanced Materials	C03C, C08F, C08L, C22C, C23C, B32B15/%, B32B17/%, B32B18/%, B32B19/%, B32B25/%, B32B27/%, B32B9/%, B82Y30/%, C01B31/%, C01B32/00, C01B32/05%, C01B32/10%, C01B32/15%, C01B32/152%, C01B32/154%, C01B32/156%, C01B32/158%, C01B32/159%, C01B32/16%, C01B32/162%, C01B32/164%, C01B32/166%, C01B32/168%, C01B32/17%, C01B32/172%, C01B32/174%, C01B32/176%, C01B32/178%, C01B32/18%, C01B32/182%, C01B32/184%, C01B32/186%, C01B32/188%, C01B32/19%, C01B32/192%, C01B32/194%, C01B32/196%, C01B32/198%, C01B32/20%, C01B32/205%, C01B32/21%, C01B32/215%, C01B32/22%, C01B32/225%, C01B32/23%, C01B32/25%, C01B32/26%, C01B32/28%, C01B32/30%, C01B32/306%, C01B32/312%, C01B32/318%, C01B32/324%, C01B32/33%, C01B32/336%, C01B32/354%, C01B32/36%, C01B32/366%, C01B32/372%, C01B32/378%, C01B32/39%, C01B32/342%, C01B32/348%, C01B32/384%, B01J39/24%, B01J41/18%, C01B32/40%, C01B32/50%, C01B32/55%, C01B32/60%, C01B32/70%, C01B32/72%, C01B32/75%, C01B32/77%, C01B32/80%, C01B32/90%, C01B32/907, C01B32/914%, C01B32/921%, C01B32/928%, C01B32/935%, C01B32/942%, C01B32/949%, C01B32/956%, C01B32/963%, C01B32/97%, C01B32/977%, C01B32/984%, C01B32/991%, C01D15/%, C01D17/%, C01F13/%, C01F15/%, C01F17/%, C04B35/%, C08J5/%, D21H17%, G02B1%, H01B3%, H01F1/0%, H01F1/12%, H01F1/34%, H01F1/42%, H01F1/44%, H01L51/30%, H01L51/46%, H01L51/54%
Nanotechnology	B81C, B82B, B82Y%
Biotechnology	A01H1/00, A01H4/00, A61K38/00, A61K39/00, A61K48/00, C02F3/34%, C07G11/00, C07G13/00, C07G15/00, C07K4/00, C07K14/00, C07K16/00, C07K17/00, C07K19/00, G01N33/53%, G01N33/54%, G01N33/55%, G01N33/57%, G01N33/68%, G01N33/74%, G01N33/76%, G01N33/78%, G01N33/88%, G01N33/92%
Energy Saving Technologies	Y02P, Y02E20/%, Y02D10/%
Solar Power	Y02E10/4%, Y02E10/5%
Wind Power	Y02E10/7%
Other (geothermal, hydropower, biomass)	Y02E10/2%, Y02E10/1%, Y02E60/30%, Y02E60/32%, Y02E60/34%, Y02E60/36%, Y02E60/50%, Y02T90/40%, Y02P90/40%, Y02P90/45%, Y02E50/17%, A01C3/02%, B01D53/84%, C02F11/04%, C05F17/02%, F23G7/10%, F24D3/18%, F24D11/02%, F24D15/04%, F24D17/02%, F24H4%, F25B30%, F25B30/02%, F25B30/04%, F25B30/06%, F24D5/12%, C10L5/46%, C10L5/48%

Technology	Approach
Clean Production Technologies	Y02P
Recycling Technologies	Y02W
Digital Transition	
Advanced Manufacturing Technologies	B03C,B07C,B23H,B23K,B23P,B23Q,B25J,G01D,G01H,G01L,G01M,G01P,G01Q,G0B,G05D,G05F ,G05G,G06M,G07C, B06B 1/6%, B06B 3/00, (G08C NOT (G01D 5/12, G05F 1/10, G07C 9/00, G01P 3/42, H01L 21/02, G05B 19/05, G01D 5/14, F02D 45/00, H01L 29/66, G05F 1/56, G05F 3/24, G07C 5/00, G05D 1/00, B60T 8/17, G05D 1/02, G01M 15/04, G01M 17/007, G07C 5/08, F02D 41/14, G05D 1/06, B60R 16/02, B62D 65/00, B60T 7/04, G01P 21/00, B60R 25/00, B62D 57/00, B60T 8/172, B60T 7/06, B62D 57/032, E05B 49/00, G01P 3/489, G05D 1/08)), (G06% AND (A21C, A22B, A22C, A23N, A24C, A41H, A42C, A43D, B01F, B02B, B02C, B03B, B03D, B05C, B05D, B07B, B08B, B21B, B21D, B21F, B21H, B21J, B22C, B23B, B23C, B23D, B23G, B24B, B24C, B25D, B26D, B26F, B27B, B27C, B27F, B27J, B28D, B30B, B31B, B31C, B31D, B31F, B41B, B41C, B41D, B41F, B41G, B41L, B41N, B42B, B42C, B44B, B65B, B65C, B65H, B67B, B67C, B68F, C13C, C13D, C13G, C13H, C14B, C23C, D01B, D01D, D01G, D01H, D02G, D02H, D02J, D03C, D03D, D03J, D04B, D04C, D05B, D05C, D06B, D06G, D06H, D21B, D21D, D21F, D21G, E01C, E02D, E02F, E21B, E21C, E21D, E21F, F04F, F16N, F26B, G01K, H05H))
Robotics	robot%
Artificial Intelligence	essentially taken from an OECD study -> https://www.oecd.org/digital/identifying-and-measuring-developments-in-artificial-intelligence-5f65ff7e-en.htm Annex Table C.1. List of AI-related keywords, Annex Table C.2. List of IPC Codes, Annex Table C.3. List of CPC codes
Big Data	((G06F17/30%, G06F19/10%, G06Q30/02%, G06F17/50%, G06N) AND (big\-data, big{-}data, hadoop, yarn, aster, datameer, fico\-blaze, fico{-}blaze, vertica, platfora, splunk ,mapreduce, map\-reduce, map{-}reduce, open\-data, open{-}data, data\-warehous%, data{-}warehous%, informatic%, data\-mine_, data{-}mine_, data\-mining, data{-}mining, simulate%, model%, analy%, artificial\-intelligence, articial{-} intelligence, neural\-network%, neural{-}network%, distributed%'(cluster%(W5)based), (cluster%(W5)comput%), (cluster%(W5)server_), (cluster%(W5)process%),(cluster%(W5)software), (cluster%(W5)application), (cloud%, based),(cloud%, comput%),(cloud%, server_),(cloud%, process%),(cloud%, software),(cloud%, application),(grid_, based),(grid_, comput%),(grid_, server_), (grid_, process%),(grid_, software), (grid_, application), croudsourc%, crowd\-sourc%, crowd{-}sourc%, massively\-parallel\-process%, massively{-}parallel{-}process%, massively\-parallel\-software, massively{-}parallel{-}software, massively\-parallel\-database_, massively{-}parallel{-}database_, distributed\-process%, distributed{-}process%, distributed\-server_, distributed{-}server_, distributed\-quer%, distributed{-}quer%, distributed\-database_, distributed{-}database_, massive\-data, massive{-}data'))
Augmented and Virtual Reality	keyword search: "Virtual Reality" OR "Augmented Reality" OR "Altered Reality" OR "Augmented Virtuality" OR "Mixed Virtuality"

Technology	Approach
Blockchain	in class G06 OR H04, keyword search: (BLOCKCHAIN* OR "BLOCK-CHAIN" OR BITCOIN* OR "BIT-COIN" OR BLOCKSIGN OR CODIUS OR "COLORED-COIN" OR "COLORED-COIN" OR CRYPTOCURRENC* OR "CRYPTO-CURRENC" OR "DISTRIBUTED LEDGER" OR DOGECOIN OR "DOGE-COIN" OR ETHEREUM OR FACTOM OR LITECOIN OR "LITE-COIN" OR "PAY-TO-SCRIPT-HASH" OR P2SH OR "PROOF-OF-STAKE" OR SIDECHAIN* OR "SMART-CONTRACT" OR SMARTCONTRACT* OR ZEROCASH OR ZCASH) OR in class H04L9/3247 OR H04L9/3249 OR H04L9/3252 OR H04L9/3255 OR H04L9/3257 OR H04L9/3236 OR H04L9/3239 OR H04L9/3242 OR H04L9/0637 OR H04L9/0643 OR H04L2209/38 OR H04L2209/56 OR H04L2209/30 OR H04L2209/46 OR H04L2209/463 OR H04L2209/466 OR G06Q20/065 OR G06Q20/0652 OR G06Q20/0655 OR G06Q20/0658 OR G06Q20/02 OR G06Q20/023 OR G06Q20/027 OR G06Q20/401 OR G06Q20/4012 OR G06Q20/4014 OR G06Q20/40145 OR G06Q20/4016 OR G06Q20/4018, keyword search: CHAINCOD* OR COUNTERPARTY OR XCP OR DIGITALCURRENC* OR "DIGITAL-CURRENC" OR ETHER OR FORKING OR FORKS OR HAWK OR LEDGER OR LISK OR "MERKLE-TREE" OR MERKLETREE OR "HASH-TREE" OR HASHTREE OR "MERKLE-ROOT" OR MERKLEROOT OR "META-COIN" OR METACOIN* OR "NAME-COIN" OR NAMECOIN* OR NXT OR "PROOF-OF-WORK" OR "HASH-CASH" OR HASHCASH OR ROOTSTOCK OR RSK OR RIPPLE OR STELLAR OR SYMBIONT OR "TYPE-COIN" OR TYPECOIN* OR ZEROCOIN OR "ZERO-COIN" OR ZEROKNOWLEDGE OR "ZERO-KNOWLEDGE") OR in class H04L2209/56, co-classification H04L9/3236 OR H04L9/3239 OR H04L9/3242 OR H04L2209/38
Cloud technologies	keyword search: "Cloud Computing"
Digital Security	G09C, H04K, G06F12/14%, G06F21/%, G06K19/%, G11C8/20%, H04L9/%, H04M1/66% , H04M1/663%, H04M1/665%, H04M1/667%, H04M1/67%, H04M1/673%, H04M1/675%, H04M1/68%, H04M1/70%, H04M1/727%, H04N7/167%, H04N7/169%, H04N7/171%,H04W12/%
Internet of Things	((A61B1/00', A61B5/00', A61B5/02%', A61B5/04%', A61B5/05%', A61B5/103%', G01S13/75%', G01V3/17%', G01V15/00', G05D1/03%', G06K7/00', G06K7/08%', G06K7/10%', G06K19/00', G06K19/06%', G06K19/07%', G06K19/077%', G08B5/22%', G08B6/00', G08B13/14%', G08B13/24%', G08B21/00', G08B25/10%', G08B29/00, G09F3/00', G09F3/03%', H01Q7/00', H01Q9/04%', H02J17/00', H04Q5/22%', H04Q7/00', H04Q9/00', H04B1/48%', H04B1/59%', H04B7/00', H04B7/08%') AND (rfid, nfc, (radio%(5W)frequency%(5W)ident%),(near(5W)field%(5W)communicat%))), H04B5%', G08C17%'
Micro- and Nanoelectronics	B82Y25/%, G01R31/26%, G01R31/27%, G01R31/28%, G01R31/303%, G01R31/304%, G01R31/317%, G01R31/327%, G09G3/14%, G09G3/32%, H01F1/40%, H01F10/193%, H01G9/028%, H01G9/032%, H01H47/32%, H01H57/%, H01L, H05K3/%, H03B5/32%, H03C3/22%, H03F3/04%, H03F3/06%, H03F3/08%, H03F3/10%, H03F3/12%, H03F3/14%,

Technology	Approach
	H03F3/16%, H03F3/183%, H03F3/21%, H03F3/343%, H03F3/387%, H03F3/55%, H03K17/72%, H05K1/%
Photonics	F21K, F21V, F21Y, G01J, G06E, H02S, G01D15/14%, G01D5/26%, G01D5/58%, G01G23/32%, G01L1/24%, G01L11/02%, G01L23/06%, G01L3/08%, G01M/11%, G01P3/36%, G01P3/38%, G01P3/68%, G01P5/26%, G01Q20/02%, G01Q30/02%, G01Q60/06%, G01Q60/18%, G01R15/22%, G01R15/24%, G01R23/17%, G01R31/308%, G01R33/032%, G01R33/26%, G01S7/481%, G01V8/%, G02B13/14%, G02B5/%, G03B/42%, G03G21/08%, G06F3/042%, G06K9/58%, G06K9/74%, G06N3/067%, G08B13/186%, G08C19/36%, G08C23/04%, G08C23/06%, G08G1/04%, G11B11/03%, G11B11/12%, G11B11/18%, G11B7/12%, G11B7/125%, G11B7/13%, G11B7/135%, G11C11/42%, G11C13/04%, G11C19/30%, H01J29/46%, H01J29/82%, H01J29/89%, H01J3/%, H01J31/50%, H01J37/04%, H01J37/05%, H01J49/04%, H01J49/06%, H01J5/16%, H01L31/052%, H01L31/055%, H01L31/10%, H01L33/06%, H01L33/08%, H01L33/10%, H01L33/18%, H01L51/50%, H01L51/52%, H01S3%, H01S5%, H02N6/%, H05B33/%, (G02B6/% NOT (G02B6/36%, G02B6/38%, G02B6/40%, G02B6/44%, G02B6/46%))

Source: Consortium

Figure 12: Technologies - Trade

Technology	HS code
Artificial intelligence and Big Data	8521, 844399, 847010, 847149, 847150, 847170, 852321, 852359, 852990, 853180, 853710, 854231, 854232, 854233, 854239, 950450
Advanced Materials and Nanotechnology	281810, 284210, 284610, 284690, 285290, 300510, 300590, 300610, 300640, 300670, 320710, 320720, 320730, 321290, 321590, 350190, 350610, 380110, 380210, 381220, 381231, 381511, 381512, 381519, 381800, 382430, 391400, 392069, 392071, 392091, 400520, 540310, 540331, 540333, 540339, 540500, 550210, 550290, 680690, 681510, 690911, 690912, 700711, 700719, 700721, 700729, 701931, 711510, 720250, 720260, 720280, 720291, 720292, 720293, 720299, 760310, 850511, 850519, 850720, 850730, 850740, 850750, 850780, 852210, 854590, 900190, 902121, 902129, 902131, 902139
Advanced Manufacturing & Robotics	820750, 820760, 841410, 841939, 841989, 842489, 842890, 845510, 845611, 845620, 845630, 845710, 845720, 845730, 845811, 845921, 845931, 845951, 845961, 846012, 846221, 846231, 846241, 847180, 847950, 847989, 848340, 848610, 848630, 848640, 851531, 851580, 902219, 902410, 902730, 902750, 903180, 903289
Energy Saving Technologies	700800, 701931, 732211, 840211, 840219, 840220, 840290, 840310, 840390, 840420, 840490, 840610, 840690, 841181, 841199, 841459, 841583, 841861, 841911, 841950, 841989, 841990, 848180, 850421, 850422, 850423, 850440, 853120, 853932, 853941, 854140, 854190, 854610, 854620, 854690, 854710, 854790, 902890, 903289, 940560

Biotechnology (including Medical Biotechnology)	3808, 210210, 210220, 220710, 290539, 291521, 291719, 291811, 291814, 292221, 292241, 292242, 293621, 294110, 300290, 350790, 382100, 382499
Internet of Things	844331, 847010, 847149, 847180, 8479, 851762, 851769, 851770, 852110, 852190, 852329, 852341, 852352, 852359, 852691, 852692, 852719, 852842, 852849, 852990, 853010, 853080, 853090, 853120, 853400, 853710, 854320, 854470, 900110, 902810, 902830, 903040, 903180
Micro- and Nanoelectronics & Photonics	7019, 9022, 700600, 700991, 701911, 701912, 701952, 841459, 845611, 848620, 848630, 848640, 848690, 852321, 852341, 852849, 852990, 853120, 853400, 853990, 854110, 854121, 854130, 854140, 854150, 854160, 854190, 854231, 854232, 854233, 854239, 854290, 854470, 900110, 900120, 900140, 900190, 900219, 900290, 900311, 900580, 900590, 900630, 900661, 900691, 900720, 901120, 901190, 901210, 901290, 901320, 901380, 901390, 901820, 901890, 902212, 902290, 902730, 902750, 902780, 903190, 903300
Digital Tech for Mobility	851220, 852359, 852610, 852691, 852990, 853010, 853080, 853090
Renewable Energy Technologies (including solar, wind, batteries, geothermal, hydropower, biomass, hydrogen)	8411, 680690, 730431, 730439, 730490, 730820, 841011, 841090, 841229, 841290, 841451, 841459, 841480, 841490, 841861, 847930, 850110, 850120, 850231, 850300, 850440, 850511, 850519, 850650, 850680, 850690, 850720, 850760, 854140, 854190, 854330, 880310, 900290
Digital Security & Networks	847010, 847180, 851762, 852190, 852321, 853110, 853120, 853400, 903040
Clean Production Technologies	843050, 844400, 847410, 847720, 847982, 902410
Recycling technologies	842121, 842139, 851420, 851430, 902410, 902519, 902580, 902610, 902620, 902680, 902710, 902780, 902810, 902820, 902830, 902890, 903020, 903031, 903210, 903281, 903290

Source: Consortium

Figure 13: Technologies – Prodcom (generation)

Technology	Prodcom code
AI	26201400, 26201700, 26202100, 26201500, 26202200, 26406050, 26403300, 26701300, 26801100, 26801300, 27904530, 27902080, 27901150, 28231000, 28232210
Advanced Materials and Nanotechnology	20135275, 20136270, 20136510, 20136520, 20136550, 20136580, 20136585, 20165670, 20165970, 20302130, 20302150, 20302170, 20593000, 20595230, 20595300, 20595400, 20595640, 20595650, 20595740, 20595940, 20602140, 20602150, 20602200, 20602320, 20602340, 20602390, 20602400, 21202420, 21202430, 21202440, 22192019, 23121210, 23121230, 23121250, 23121270, 23441100, 23441210, 23441230, 23991400, 23991500,

Technology	Prodcom code
	24101240, 24101250, 24101255, 24101265, 24101270, 24101280, 24101285, 24101295, 24422100, 24422450, 26112220, 26112240, 26114010, 26114070, 26702153, 27202310, 27202320, 27202330, 27202340, 27202350, 27202395, 27901390, 32502235, 32502253, 32502255, 32502259, 32502290, 32504153, 32504155, 32504159, 32504170, 32504290, 32505010, 32505020
Advanced Manufacturing & Robotics	26112260, 26115050, 26115020, 26113003, 26121080, 26516500, 26515235, 26518550, 26517015, 26515330, 26515135, 26516350, 26516330, 26515239, 26514500, 26516200, 26515271, 26515175, 26517019, 26515283, 26516690, 26515381, 26601170, 26601119, 26702450, 26801300, 27903154, 27903181, 28152475, 28221840, 28296050, 28292240, 28412220, 28412123, 28412240, 28412300, 28411240, 28411270, 28412217, 28413120, 28412130, 28411220, 28413140, 28413310, 28411140, 28411120, 28413240, 28411150, 28491340, 28491310, 28992020, 28993945, 28993935, 28992040, 28992060
Big Data and Cloud Computing	26201500, 26202100, 26801300, 26801100, 27904530, 28231000
Energy Saving Technologies	25211300, 25211200, 25211100, 25301110, 25301170, 26114070, 26112220, 26304065, 27123150, 27401550, 27401570, 27402400, 27521400, 27902020, 27904155, 27902050, 27904153, 27904140, 28141253, 28251270, 28251380, 28251130
Biotechnology (including Medical Biotechnology)	10891350, 10891339, 10891334, 20143271, 20147400, 20144290, 20142338, 20143473, 20146470, 20143382, 20143475, 20201590, 20595994, 20595957, 21105100, 21105400, 21102020, 21102010
Internet of Things	26121080, 26122000, 26123000, 26201800, 26201400, 26202200, 26203000, 26302320, 26302370, 26304065, 26401100, 26405190, 26512020, 26512060, 26518110, 26512080, 26516370, 26514400, 26516330, 26511190, 26516690, 26801200, 26801300, 27201140, 27201175, 27201155, 27201170, 27201200, 27201110, 27201125, 27201120, 27201130, 27201190, 27201115, 27201150, 27201160, 27311200, 27311100, 27904530, 27903330, 27902050, 27907030, 27903370, 27907010
Micro- and Nanoelectronics & Photonics	26113067, 26113023, 26112220, 26113065, 26112240, 26112180, 26114070, 26113091, 26113034, 26112150, 26113003, 26112120, 26113006, 26113027, 26113080, 26113054, 26112280, 26113094, 26112260, 26202200, 26304065, 26403400, 26405190, 26512020, 26518110, 26515330, 26601130, 26601170, 26601300, 26601115, 26702450, 26702155, 26702270, 26702153, 26702180, 26702250, 26701650, 26701250, 26702310, 26702230, 26702170, 26702390, 26702330, 26702490, 26701910, 26701100, 26801200, 27311200, 27311100, 27403010, 27403030, 27402500, 27902050, 28411120, 32501335
Digital Tech for Mobility	26304065, 26405190, 26518110, 26512020, 26511190, 26512060, 26801300, 27903330, 27907010, 27907030, 30201100
Renewable Energy Technologies (including solar, wind, batteries,	23991930, 24201400, 24201350, 24201330, 24201370, 25112200, 26114070, 26112240, 26702155, 26701100, 27116110, 27201200, 27202350, 27201155, 27201190, 27202230, 27201160, 27202240, 27201150, 27904200, 27904153, 27904155, 28112200, 28113200, 28112400, 28121200, 28122000, 28132800, 28133200, 28251380, 28251130, 28491287, 28491283, 30114050, 30305030

Technology	Prodcom code
geothermal, hydropower, biomass, hydrogen)	
Digital Security & Networks	26113054, 26113027, 26113080, 26114090, 26113065, 26113067, 26113034, 26122000, 26123000, 26203000, 26202200, 26305020, 26305080, 26514400, 26801100, 26801300, 27902050

Source: Consortium

Figure 14: Technologies – Prodcom (diffusion)

Technology	Prodcom code
AI	18202070, 18203030, 18203050, 18201070, 18203070, 26203000, 26201660, 26204000, 26302370, 26304060, 26304010, 26302320, 26401100, 26403200, 26404400, 26401270, 26403100, 26404370, 26404270, 26401290, 26404359, 26402090, 26701650, 26701100, 26801200, 27116208, 27123130, 27123150, 27907030, 27902050, 27902020, 27903350, 27904140, 27903330, 27907010, 28252010, 30204060, 30204050
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Technology	Prodcom code
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Technology	Prodcom code
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Big Data and Cloud Computing	18201070, 18202070, 18203050, 18203070, 18203030, 26201300, 26204000, 26202200, 26201660, 26201100, 26203000, 26201400, 26302370, 26302320, 26304010, 26304060, 26403100, 26404359, 26401290, 26404370, 26402090, 26404400, 26403200, 26401100, 26404270, 26401270, 26801200, 27116208, 27123130, 27904140, 27903350, 27902080, 28252010
Energy Saving Technologies	23121330, 23192100, 23192500, 23192400, 23431050, 23431030, 23491230, 23991930, 24104150, 24104130, 24105310, 24512000, 25291120, 25301150, 25301330, 25301350, 25301230, 26115020, 26115050, 26114090, 26202100, 26201700, 26203000, 26201500, 26403400, 26517019, 26517015, 27115013, 27121090, 27121020, 27122330, 27122350, 27122230, 27123130, 27122250, 27122370, 27201150, 27201190, 27201155, 27201200, 27201160, 27331100, 27331360, 27331330, 27331350, 27331380, 27331310, 27401300, 27402200, 27512900, 27512560, 27512123, 27512450, 27511400, 27512890, 27512870, 27512310, 27512125, 27512170, 27512330, 27512410, 27512370, 27512690, 27512530, 27513030, 27512430, 27512490, 27512810, 27512650, 27513070, 27512200, 27513050, 27511133, 27511530, 27512850, 27512630, 27512350, 27512830, 27521270, 27521113, 27521234, 27521115, 27521300, 27521250, 27521190, 27522000, 27901230, 27901280, 27905100, 28131417, 28141313, 28211351, 28211354, 28211470, 28211270, 28211230, 28253010, 28251333, 28253080, 28253070, 28251360, 28251250, 28251220, 28251335, 28251240, 28296090, 28294330, 28296030
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Micro- and Nanoelectronics & Photonics	20591150, 20591200, 20591130, 20591170, 25302100, 25302200, 25301150, 26114090, 26115050, 26115020, 26114040, 26111200, 26123000, 26121080, 26122000, 26201100, 26202100, 26201700, 26201500, 26201610, 26201400, 26203000, 26201620, 26201650, 26201300, 26201800, 26201660, 26201200, 26301100, 26302320, 26302330, 26301200, 26304039, 26302310, 26301300, 26302100, 26302370, 26305020, 26302200, 26305080, 26401290, 26404400, 26404370, 26404359, 26404270, 26403300, 26401270, 26401100, 26402090, 26406050, 26404355, 26513300, 26516430, 26516453, 26511120, 26511190, 26514300, 26512080, 26511150, 26515383, 26516455, 26511180, 26517090, 26515139, 26511200, 26512060, 26521300, 26521400, 26522470, 26521100, 26522440, 26522410, 26521200, 26601450, 26601433, 26601230, 26601150, 26601280, 26701400, 26701990, 26702420, 26701300, 26701500, 26801400, 26801300, 27116205, 27115050, 27114260, 27114180, 27114220, 27114150, 27114380, 27116203, 27114330, 27116110, 27114120, 27116208, 27115080, 27114240, 27124030, 27123170, 27123203, 27123205, 27201170, 27201200, 27201160, 27202340, 27201175, 27201150, 27201125, 27201190, 27202330, 27201110, 27202350, 27201115, 27201130, 27201120, 27202310, 27202320, 27202395, 27201155, 27201140, 27403090, 27402400, 27401100, 27401570, 27401293, 27402200, 27401510, 27401530, 27401295, 27402100, 27401250, 27905300, 27904190, 27905240, 27907010, 27904155, 27901150, 27904170, 27905100, 27907030, 27905220, 27906037, 27904510, 27904200, 27904140, 27902020, 27904130, 27904153, 27904530, 28112400, 28141313, 28231000, 28232110, 30304000, 32504250, 32504153, 32504130, 32504159, 32501150, 32504155, 32504290, 32504170, 32501320, 32501200, 32911210

Technology	Prodcom code
Digital Tech for Mobility	18203070, 18203030, 18203050, 26122000, 26302200, 26302370, 26304010, 26403300, 26401290, 26401270, 26516453, 26512080, 26518450, 26521300, 26702310, 26701300, 27124090, 27124030, 27903350, 27902080, 27902050, 27904530, 27902020, 28252010, 29312330, 29312350, 30204050, 30204060, 30304000
Renewable Energy Technologies (including solar, wind, batteries, geothermal, hydropower, biomass, hydrogen)	25291200, 25291110, 25301350, 25301250, 26515383, 26515283, 26516370, 26515274, 26515289, 26515271, 26515259, 26515381, 26518433, 26518435, 26515395, 26516330, 27114150, 27114180, 27114120, 27114380, 27114330, 27114240, 27114260, 27114220, 27122250, 27123170, 27123203, 27123205, 27121090, 27122230, 27121020, 27202420, 27202395, 27202410, 27321200, 27321400, 27321100, 27321380, 27331360, 27331380, 27905240, 27906035, 27906057, 27906055, 27901350, 27908200, 27905100, 27901330, 27901280, 27906080, 27905220, 27906037, 27908100, 28112300, 28112160, 28113300, 28113100, 28121480, 28121530, 28121450, 28121580, 28131380, 28211430, 28211150, 28251150, 30112270, 30114030
Digital Security & Networks	18203050, 18203070, 18202070, 18203030, 26112220, 26111100, 26112260, 26112150, 26112180, 26112240, 26112280, 26113023, 26112120, 26113003, 26115050, 26113091, 26115020, 26114070, 26113094, 26113006, 26201700, 26201200, 26304010, 26302370, 26301100, 26302340, 26301300, 26303000, 26304060, 26301200, 26304039, 26304050, 26302330, 26302310, 26304035, 26302200, 26302100, 26304040, 26403300, 26404400, 26402020, 26404355, 26403400, 26402090, 26402040, 26521400, 26701300, 29312330

Source: Consortium

Appendix D: Survey questionnaire

The first important objective of this company survey is to understand the share of SMEs and large companies in different industries that have adopted or are planning to adopt advanced digital transition technologies and green transition technologies. It is equally important to better assess the share of companies that have not adopted any advanced digital and green technologies. Secondly, there is a number of information that we will need to know about those that use/adopt these technologies in order to be able to analyse industrial transformation. To implement the survey, various aspects require dedicated attention:

IMPORTANCE OF THIS STUDY

- Please explain and highlight to the interviewees that this survey is part of a key study of the European Commission and feeds into the reflections about the EU industrial strategy and clean industrial deal and discussions about the industrial competitiveness of the EU resulting in better policies, support measures and regulations. This is why it is very important, and the responses are highly appreciated.

COMPLETENESS OF INFORMATION

- It is highly important that if a company adopted a technology, it provides responses to all corresponding questions (in the case of the green transition, it responds to all environment related questions). We need fully filled in questionnaires for the technologies that the company adopted.

TECHNOLOGY DEFINITIONS:

- The survey has a focus on the one hand on advanced digital technologies. It is very important to understand the definitions of these technologies and explain it to the interviewees in case there are any doubts.

QUALIFYING QUESTIONS

*** 1. What is the main activity of your company?**

- Agri-food
- Construction
- Cultural and creative: News media
- Cultural and creative: Audiovisual
- Cultural and creative: Music
- Cultural and creative: Arts (performing arts, visual art)
- Cultural and creative: Heritage (heritage, museums)
- Cultural and creative: Video games
- Cultural and creative: Design
- Electronics
- Energy-intensive industries (chemicals, steel, paper, plastics, mining, extraction and quarrying, refineries, cement, wood, rubber, non-ferrous metals, glass and ceramics)
- Retail
- Textiles
- Tourism
- Mobility, transport and automotive
- Aerospace and Defence (we capture only aerospace)
- Health (pharmaceuticals and medical devices)
- Social Economy
- If other, please specify

*** 2. Which of the following best describes your position within your organisation?**

- CEO, Managing Director, Owner, Founder, General Manager
- Head of IT/ ICT/ Digitalisation/Digital Transformation Lead/Digital Manager
- Head of Sustainability/Environment/Green transformation
- COO/Head of Operations
- Technology Officer/Technical Manager
- Project manager
- Other:

.....

*** 3. Does your company use (has adopted) any advanced digital technologies such as Artificial Intelligence, Robotics, Cloud computing, Big Data, Internet of Things, Augmented and Virtual Reality, Blockchain, Edge Computing, Digital twins?**

- Yes
- No

*** 4. Does your company use (has adopted) any environmental green technologies such as recycling, clean industrial technologies, energy-saving technologies, advanced materials, biotechnology, circular industrial business models, renewable energy?**

- Yes
- No

INTRODUCTION

5. How many full-time employees does your organisation have? Note: A full-time employee is equivalent to one employee working full-time hours

- Less than 10
- Between 10-99
- Between 100-249
- Between 250-499
- More than 500

6. What was the level of turnover of your company in 2023?

- Less than 25,000 euro
- From 25,000 to 50,000 euro
- From 50,000 to 100,000 euro
- From 100,000 to 250,000 euro
- From 250,000 to 500,000 euro
- From 500,000 to 2 million euro
- From 2 to 10 million euro
- From 10 to 50 million euro
- More than 50 million euro
- Don't know/Refuse to answer

7. How has your company's turnover changed over the past two years?
Increased significantly (more than 10%)
Increased slightly (1-10%)
Stayed the same
Decreased slightly (1-10%)
Decreased significantly (more than 10%)

8. Does your company have a concrete strategy in place for digital transformation? Note: A concrete strategy or a set of coordinated strategies must have a dedicated budget and resources and must include clear and defined measurable goals to monitor the progress of the company's digital transformation.

- Yes
- No

9. Does your company have a concrete strategy in place to reduce its carbon footprint and become climate neutral or negative? Note: A concrete strategy or a set of coordinated strategies must have a dedicated budget and resources and must include clear and defined measurable goals to monitor the progress of the company's green transformation.

- Yes
- No

ADOPTION OF TECHNOLOGIES

10. Which advanced digital technologies does your company use or has your company recently adopted?

- Artificial Intelligence and Big Data
- Robotics
- Cloud computing
- Internet of Things
- Augmented and Virtual Reality
- Blockchain
- Micro and nanoelectronics and Photonics
- Edge computing
- Cybersecurity

11. Does your company plan to use any advanced digital technologies such as Artificial Intelligence, Robotics, Cloud computing, Big Data, Internet of Things, Augmented and Virtual Reality, Blockchain, Edge Computing, Micro and nanoelectronics and photonics over the next two years?

- Yes
- No

12. Which advanced digital technologies is your company planning to use or adopt?

- Artificial Intelligence and Big Data
- Robotics
- Cloud computing
- Internet of Things
- Augmented and Virtual Reality
- Blockchain
- Micro and nanoelectronics and Photonics
- Edge computing
- Cybersecurity

13. Which environmental technologies and measures has your company adopted or implemented? .

- Renewable energy
- Energy-saving technologies
- Advanced materials
- Biotechnology
- Clean production technologies
- Waste management technologies
- Recycling
- Carbon capture technologies
- Circular industrial business models

14. Does your company plan to adopt any environmental technologies or does it plan to implement any environmental measures such as recycling, clean industrial technologies, energy-saving technologies, advanced materials, biotechnology circular industrial business models, renewable energy over the next two years?

- Yes
- No

15. Which environmental technologies and measures is your company planning to adopt or implement?

- Renewable energy
- Energy-saving technologies
- Advanced materials
- Biotechnology
- Clean production technologies
- Waste management technologies
- Recycling
- Carbon capture technologies
- Circular industrial business models (sharing, leasing, renting, remanufacturing, reusing etc)

DIGITAL TECHNOLOGY SPECIFIC QUESTIONS

CLOUD COMPUTING

For all qualified companies; selecting cloud computing in Q10

16. Over the past year, how much has your company invested on average in cloud computing?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don't know/No answer

17. Is your company planning to buy any cloud computing services used over the internet in the coming year?

- Yes
- No

If yes

18. In the next year, how much is your company planning to invest on average in cloud computing?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don’t know/No answer

19. Has your company implemented any innovations in the past two years that leverage cloud computing technologies? (eg cloud-based data analytics, cloud-hosted customer relationship management, cloud-based product design etc)

- Yes
- No

If yes, please elaborate

20. In your assessment, has the adoption of cloud computing increased your productivity? Note: Productivity is proxied by the output per hour worked

- Increased
- Decreased
- No change

If increased

21. Could you please estimate the percentage increase in productivity? Note: Productivity is proxied by the output per hour worked. Insert as percentage e.g. 1%.

If decreased

22. Please elaborate why

23. In your assessment, has the adoption of cloud computing increased or decreased your production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labour, and indirect costs such as rent, utilities (electricity, water, etc.), maintenance, and repairs.

- Increased
- Decreased
- No change

If increased

24. Could you please estimate the percentage increase in production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labour, and indirect costs such as rent, utilities (electricity, water, etc.), maintenance, and repairs. Insert as percentage e.g. 1%.

If decreased

25. Please elaborate why

ROBOTICS

For all qualified companies selecting robotics in Q10

26. What is the country of origin of the service provider who installed the robots for you?

- Same country as mine
- EU27
- USA
- China
- Other: .....
- Don't know/Refuse to answer

27. Over the past year, how much has your company invested on average in robotics?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don't know/No answer

28. Is your company planning to use any types of robots in the coming year?

- Yes
- No

If yes

29. In the next year, how much is your company planning to invest on average in robotics?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don’t know/No answer

30. Has your company implemented any innovations in the past two years that leverage robotics?

- Yes
- No

If yes, please elaborate

31. In your assessment, has the adoption of robotics increased or decreased your productivity? Note: Productivity is proxied by the output per hour worked.

- Increased
- Decreased
- No change

If increased

32. Could you please estimate the percentage increase in productivity? Note: Productivity is proxied by the output per hour worked. Insert as percentage e.g. 1%.

If decreased

33. Could you please estimate the percentage decrease in productivity? Note: Productivity is proxied by the output per hour worked. Insert as percentage e.g. -1%

34. In your assessment, has the adoption of robotics increased or decreased your production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc.

- Increased
- Decreased
- No change

If increased

35. Could you please estimate the percentage increase in production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc. Insert as percentage e.g. 1%

If decreased

36. Could you please estimate the percentage decrease in production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labour and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc. Insert as percentage e.g. -1%

37. Has the adoption of robotics allowed you to manage company operations with less employees?

- Yes
- No

If yes

38. If yes, which job titles does this technology affect?

ARTIFICIAL INTELLIGENCE AND BIG DATA

For all qualified companies; selecting Artificial Intelligence and Big Data in Q10

39. How does your company primarily use AI to gain a competitive advantage?

- We use publicly available AI tools (e.g., ChatGPT, Copilot, Bard).
- We integrate third-party AI solutions into our processes.
- We develop AI models and systems in-house

40. What type of AI technologies does your company use?

- Machine Learning – Algorithms that learn from data to improve decision-making.
- Deep Learning – Advanced neural networks for tasks like image and speech recognition.
- Natural Language Processing (NLP) – AI for understanding and generating human language (e.g., chatbots, text analysis).
- Computer Vision – AI for processing and interpreting images or videos.
- Generative AI – AI models that create new content, such as text, images, or music
- Robotic Process Automation (RPA) – AI-driven automation of repetitive tasks.
- Predictive Analytics – AI used for forecasting trends and behaviors.
- Speech Recognition & Synthesis – AI for transcribing or generating speech (e.g., voice assistants).
- Recommendation Systems – AI-driven personalisation for user preferences (e.g., product or content recommendations).
- Autonomous Systems – AI for self-operating machines or vehicles.

41. Over the past year, how much has your company invested on average in artificial intelligence?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don't know/No answer

42. Is your company planning to use artificial intelligence in the coming year?

- Yes
- No

If yes

43. In the next year, how much is your company planning to invest on average in artificial intelligence?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don’t know/No answer

44. Who develops AI-based systems for your company?

- Own employees
- External service provider
- Both own employees and external service providers

If external or both

45. What is the country of origin of your external service provider?

List of countries in drop down menu

46. Do you use any of the following providers and AI tools?

- IBM Watson
- Google Cloud AI
- Microsoft Azure AI
- Amazon Web Services (AWS) AI/ML
- OpenAI (chatGPT)
- DeepAI
- Other, please specify: .....
- None of the above

47. In which part of your business operations do you use or planning to use artificial intelligence?

- Material sourcing
- Product/service design
- Production processes
- Service provision
- Marketing/sales
- Supply chain management
- Human resources and recruiting
- Business administration
- Finance
- Other, please specify: .....

48. Which tasks do you currently use or plan to use artificial intelligence for?

- Data analysis
- Automation
- Quality control/error detection
- Cybersecurity
- Decision-making
- Reduction of waste or use of resources
- Creating new content
- Other, please specify: .....

49. Has your company implemented any innovations in the past two years that leverage Artificial Intelligence?

- **Yes**
- **No**

If yes, please elaborate

50. In your assessment, has the adoption of artificial intelligence increased or decreased your productivity? Note: Productivity is proxied by the output per hour worked

- Increased
- Decreased
- No change

If increased

51. Could you please estimate the percentage increase in productivity? Note: Productivity is proxied by the output per hour worked. Insert as percentage e.g. 1%

If decreased

52. Could you please estimate the percentage decrease in productivity? Note: Productivity is proxied by the output per hour worked. Insert as percentage e.g. -1%

53. In your assessment, has the adoption of artificial intelligence increased or decreased your production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc.

- Increased
- Decreased
- No change

If increased

54. Could you please estimate the percentage increase in production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc. Insert as percentage e.g. 1%

If decreased

55. Could you please estimate the percentage decrease in production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc. Insert as percentage e.g. -1%

56. Has the adoption of artificial intelligence allowed you to manage company operations with less employees?

- Yes
- No

If yes

57. If yes, how many employees have you managed to spare? (Please provide an estimate for the number of employees)

If yes

58. If yes, which job titles does artificial intelligence affect?

AUGMENTED AND VIRTUAL REALITY

For all qualified companies; selecting augmented and virtual reality in Q10

59. Over the past year, how much has your company invested on average in Augmented or Virtual Reality?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don't know/No answer

60. How do you use Augmented or Virtual Reality in your company?

- To offer a virtual interface (virtual tour) for our customers
- Developing an immersive experience
- Training and simulation
- Virtual training and simulation
- Virtual product design
- Virtual production
- As part of wearable devices
- Other, please specify: .....

61. Is your company planning to use Augmented or Virtual Reality in the coming year?

- Yes
- No

If yes

62. In the next year, how much is your company planning to invest on average in Augmented or Virtual Reality?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don't know/No answer

63. Has your company implemented any innovations in the past two years that leverage AVR?

- **Yes**
- **No**

If yes, please elaborate

64. Who develops Augmented reality services for your company?

- Own employees
- External service provider
- Both own employees and external service providers

If external or both

65. What is the country of origin of your external service provider?

List of countries in drop down menu

66. In your assessment, has the adoption of Augmented or Virtual Reality increased or decreased your productivity? Note: Productivity is proxied by the output per hour worked

- Increased
- Decreased
- No change

If increased

67. Could you please estimate the percentage increase in productivity? Note: Productivity is proxied by the output per hour worked. Insert as percentage e.g. 1%.

If decreased

68. Could you please estimate the percentage decrease in productivity? Note: Productivity is proxied by the output per hour worked. Insert as percentage e.g. -1%

69. In your assessment, has the adoption of Augmented or Virtual Reality increased or decreased your production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc.

- Increased
- Decrease
- No change

If increased

70. Could you please estimate the percentage increase in production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc. Insert as percentage e.g. 1%.

If decreased

71. Could you please estimate the percentage decrease in production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc. Insert as percentage e.g. -1%.

INTERNET OF THINGS

For all qualified companies; selecting Internet of things in Q10

72. Over the past year, how much has your company invested on average in the Internet of Things?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don't know/No answer

73. Is your company planning to use the Internet of Things in the coming year?

- Yes
- No

If yes

74. In the next year, how much is your company planning to invest on average in the Internet of Things?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don’t know/No answer

75. Has your company implemented any innovations in the past two years that leverage IoT?

- **Yes**
- **No**

If yes, please elaborate

76. In your assessment, has the adoption of the Internet of Things increased or decreased your productivity? Note: Productivity is proxied by the output per hour worked

- Increased
- Decreased
- No change

If increased

77. Could you please estimate the percentage increase in productivity? Note: Productivity is proxied by the output per hour worked. Insert as percentage e.g. 1%

If decreased

78. Could you please estimate the percentage decrease in productivity? Note: Productivity is proxied by the output per hour worked. Insert as percentage e.g. -1%

79. In your assessment, has the adoption of the Internet of Things increased or decreased your production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc.

- Increased
- Decreased
- No change

If increased

80. Could you please estimate the percentage increase in production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc. Insert as percentage e.g. 1%

If decreased

81. Could you please estimate the percentage decrease in production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc. Insert as percentage e.g. -1%

BLOCKCHAIN

For all qualified companies; selecting blockchain in Q10

82. Over the past year, how much has your company invested on average in blockchain?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don't know/No answer

83. Is your company planning to use blockchain in the coming year?

- Yes
- No

If yes

84. In the next year, how much is your company planning to invest on average in blockchain?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don’t know/No answer

85. Has your company implemented any innovations in the past two years that leverage blockchain solutions?

- Yes
- No

If yes, please elaborate

86. In your assessment, has the adoption of blockchain increased or decreased your productivity? Note: Productivity is proxied by the output per hour worked

- Increased
- Decreased
- No change

If increased

87. Could you please estimate the percentage increase in productivity? Note: Productivity is proxied by the output per hour worked. Insert as percentage e.g. 1%

If decreased

88. Could you please estimate the percentage decrease in productivity? Note: Productivity is proxied by the output per hour worked. Insert as percentage e.g. -1%

89. In your assessment, has the adoption of blockchain increased or decreased your production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc.

- Increased
- Decreased
- No change

If increased

90. Could you please estimate the percentage increase in production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc. Insert as percentage e.g. 1%.

If decreased

91. Could you please estimate the percentage decrease in production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc. Insert as percentage e.g. -1%

EDGE COMPUTING

For all qualified companies; selecting edge computing in Q10

92. Over the past year, how much has your company invested on average in edge computing?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don't know/No answer

93. Is your company planning to use edge computing in the coming year?

- Yes
- No

If yes

94. In the next year, how much is your company planning to invest on average in edge computing?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don't know/No answer

95. Has your company implemented any innovations in the past two years that leverage edge computing?

- Yes
- No

If yes, please elaborate

96. In your assessment, has the adoption of edge computing increased or decreased your productivity? Note: Productivity is proxied by the output per hour worked

- Increased
- Decreased
- No change

If increased

97. Could you please estimate the percentage increase in productivity? Note: Productivity is proxied by the output per hour worked. Insert as percentage e.g. 1%.

If decreased

98. Could you please estimate the percentage decrease in productivity? Note: Productivity is proxied by the output per hour worked. Insert as percentage e.g. -1%

99. In your assessment, has the adoption of edge computing increased or decreased your production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc.

- Increased
- Decreased
- No change

If increased

100. Could you please estimate the percentage increase in costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc. Insert as percentage e.g. 1%.

If decreased

101. Could you please estimate the percentage decrease in costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc. Insert as percentage e.g. -1%.

102. Do you use the services of any European Data Space? (The Common European Data Spaces are expected to make more data available for access and reuse for companies around the EU. More information: https://digital-strategy.ec.europa.eu/en/policies/data-spaces

- Yes
- No

If yes

103. If yes, please explain for which specific purposes:

MICRO -NANOELECTRONICS AND PHOTONICS

For all qualified companies; selecting micro- and nanoelectronics and photonics in Q1

104. Over the past year, how much has your company invested on average in micro- and nanoelectronics and photonics or related products?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don't know/No answer

If yes

105. In the next year, how much is your company planning to invest on average in micro- and nanoelectronics and photonics or related products?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don't know/No answer

106. Has your company implemented any innovations in the past two years that leverage micro and nanoelectronics or photonics?

- Yes
- No

If yes, please elaborate

107. In your assessment, has the adoption of micro- and nanoelectronics and photonics increased your productivity? Note: Productivity is proxied by the output per hour worked

- Increased
- Decreased
- No change

If increased

108. Could you please estimate the percentage increase in productivity? Note: Productivity is proxied by the output per hour worked. Insert as percentage e.g. 1%.

If decreased

109. Could you please estimate the percentage decrease in productivity? Note: Productivity is proxied by the output per hour worked. Insert as percentage e.g. -1%.

110. In your assessment, has the adoption of micro- and nanoelectronics and photonics increased or decreased your production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labour, and indirect costs such as rent, utilities (electricity, water, etc.), maintenance, and repairs.

- Increased
- Decreased
- No change

If increased

111. Could you please estimate the percentage increase in production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labour, and indirect costs such as rent, utilities (electricity, water, etc.), maintenance, and repairs. Insert as percentage e.g. 1%.

If decreased

112. Could you please estimate the percentage decrease in production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labour, and indirect costs such as rent, utilities (electricity, water, etc.), maintenance, and repairs. Insert as percentage e.g. -1%

CYBERSECURITY

For all qualified companies; selecting Cybersecurity in Q5

113. In which application areas does your company use cybersecurity?

- Bio-based materials
- Bioenergy and biofuels
- Environmental for example bioremediation, wastewater treatment, carbon capture using microbes
- Bio-based products

Other, please elaborate

114. Over the past year, how much has your company invested on average in Cybersecurity?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don't know/No answer

115. Is your company planning to use Cybersecurity in the coming year?

- Yes
- No

If yes

116. In the next year, how much is your company planning to invest on average in Cybersecurity?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don’t know/No answer

117. In your assessment, has the adoption of Cybersecurity increased or decreased your productivity? Note: Productivity is proxied by the output per hour worked

- Increased
- Decreased
- No change

If increased

118. Could you please estimate the percentage increase in productivity? Note: Productivity is proxied by the output per hour worked. Insert as percentage e.g. 1%

If decreased

119. Could you please elaborate why

120. In your assessment, has the adoption of Cybersecurity increased or decreased your production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc.

- Increased
- Decreased
- No change

If increased

121. Could you please estimate the percentage increase in production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labour and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc. Insert as percentage e.g. 1%

If decreased

122. Could you please elaborate why

GREEN TECHNOLOGY ADOPTION

123. Is your company certified on any environmental standards?

- Yes
- No

If yes

124. If yes, on which environmental standards?

- ISO
- EMAS
- Fair Trade
- EU Ecolabel
- GOTS
- Other, please specify: .....

ADVANCED MATERIALS

For all qualified companies; selecting Advanced Materials in Q13

.

125. What type of advanced materials has your company adopted over the past years?

- Electronics Materials
- Energy-related Materials
- Materials for Surfaces & Interfaces
- Polymeric Materials & Precursors
- Structural Materials & Composites
- Recycled Materials
- Bio-based Materials
- Other:

126. Have you introduced new products based on advanced materials over the past years?

- Yes
- No
- Please explain

127. From which geography are you sourcing your advanced materials from?

- EU national
- EU another country
- Other European
- USA
- Asia
- Africa
- South America
- Other international

128. Over the past year, how much has your company invested on average in Advanced Materials?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don't know/No answer

129. Is your company planning to use Advanced Materials in the coming year?

- Yes
- No

If yes

130. In the next year, how much is your company planning to invest on average in Advanced Materials?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don't know/No answer

131. In your assessment, has the adoption of Advanced Materials increased or decreased your productivity? Note: Productivity is proxied by the output per hour worked

- Increased
- Decreased
- No change

If increased

132. Could you please estimate the percentage increase in productivity? Note: Productivity is proxied by the output per hour worked. Insert as percentage e.g. 1%

If decreased

133. Please explain why

134. In your assessment, has the adoption of Advanced Materials increased or decreased your production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc.

- Increased
- Decreased
- No change

If increased

135. Could you please estimate the percentage increase in production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc. Insert as percentage e.g. 1%

If decreased

136. Could you please estimate the percentage decrease in production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labour and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc. Insert as percentage e.g. -1%

BIOTECHNOLOGY

For all qualified companies; selecting Biotechnology in Q13

137. In which applications does your company use biotechnology?

- Bio-based materials
- Bioenergy and biofuels
- Environmental for example bioremediation, wastewater treatment, carbon capture using microbes
- Bio-based products

Other, please elaborate

138. Over the past year, how much has your company invested on average in Biotechnology?

- Nothing
- Less than €50,000
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don't know/No answer

139. Is your company planning to use Biotechnology in the coming year?

- Yes
- No

If yes

140. In the next year, how much is your company planning to invest on average in Biotechnology?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don't know/No answer

126. Has your company implemented any innovations in the past two years that leverage biotechnology?

- Yes
- No
- Please explain

129. In your assessment, has the adoption of Biotechnology increased or decreased your productivity? Note: Productivity is proxied by the output per hour worked

- Increased
- Decreased
- No change

If increased

130. Could you please estimate the percentage increase in productivity? Note: Productivity is proxied by the output per hour worked. Insert as percentage e.g. 1%

If decreased

131. Could you please elaborate why

132. In your assessment, has the adoption of Biotechnology increased or decreased your production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc.

- Increased
- Decreased
- No change

If increased

133. Could you please estimate the percentage increase in production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc. Insert as percentage e.g. 1%

If decreased

134. Could you please elaborate why

RECYCLING

For all qualified companies; selecting Recycling in Q13

135. What recycling practices has your company implemented to reduce waste and promote sustainability?

- Material recycling
- Product circularity and reuse
- Sorting
- Offering waste of your company to another industry
- Sourcing waste of another industry as an input to your production

Other, please elaborate

136. Over the past year, how much has your company invested on average in Recycling?

- Nothing
- Less than €50,000
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don't know/No answer

137. Is your company planning to use Recycling in the coming year?

- Yes
- No

If yes

138. In the next year, how much is your company planning to invest on average in Recycling?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don’t know/No answer

139. In your assessment, has the adoption of Recycling increased or decreased your productivity? Note: Productivity is proxied by the output per hour worked

- Increased
- Decreased
- No change

If increased

140. Could you please estimate the percentage increase in productivity? Note: Productivity is proxied by the output per hour worked. Insert as percentage e.g. 1%

If decreased

141. Could you please elaborate why

142. In your assessment, has the adoption of Recycling increased or decreased your production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc.

- Increased
- Decreased
- No change

If increased

143. Could you please estimate the percentage increase in production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc. Insert as percentage e.g. 1%

If decreased

144. Could you please elaborate why

ENERGY SAVING TECHNOLOGIES

For all qualified companies; selecting Energy Saving Technologies in Q13

145. In which applications does your company use energy-saving technologies?

Other, please elaborate

146. Over the past year, how much has your company invested on average in Energy Saving Technologies?

- Nothing
- Less than €50,000
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don't know/No answer

147. Is your company planning to use Energy Saving Technologies in the coming year?

- Yes
- No

If yes

148. In the next year, how much is your company planning to invest on average in Energy Saving Technologies?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don’t know/No answer

149. In your assessment, has the adoption of Energy Saving Technologies increased or decreased your productivity? Note: Productivity is proxied by the output per hour worked

- Increased
- Decreased
- No change

If increased

150. Could you please estimate the percentage increase in productivity? Note: Productivity is proxied by the output per hour worked. Insert as percentage e.g. 1%

If decreased

151. Could you please elaborate why

152. In your assessment, has the adoption of Energy Saving Technologies increased or decreased your production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc.

- Increased
- Decreased
- No change

If increased

153. Could you please estimate the percentage increase in production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc. Insert as percentage e.g. 1%

If decreased

154. Could you please elaborate why

CIRCULAR ECONOMY BUSINESS MODELS

For all qualified companies; selecting Circular Economy Business Models in Q13

155. What type of circular economy business models have you adopted?

- Remanufacturing
- Renting, leasing and related service models
- Repair and maintenance services
- Resell, reuse
- Circular design (products that can be disassembled and recycled)
- Design for durability (products that can last longer)

156. Has your organisation provided services or products that support short value chains in any industrial ecosystem? By "short value chains" we refer to products or services that promote local production and consumption or promote direct relationships in terms of coordination, social connection and collaboration.

- Yes
- No

If yes

156. For which of the following ecosystems?

- Agri-food
- Construction
- Cultural and creative: News media
- Cultural and creative: Audiovisual
- Cultural and creative: Music
- Cultural and creative: Arts and Heritage (performing arts, visual art, heritage, museums)
- Cultural and creative: Video games
- Electronics
- Energy-intensive industries (chemicals, steel, paper, plastics, mining, extraction and quarrying, refineries, cement, wood, rubber, non-ferrous metals, glass and ceramics)
- Retail
- Textiles
- Tourism
- Social economy
- Mobility, transport and automotive
- Aerospace and Defence
- Health (pharmaceuticals and medical devices)
- If other, please specify

157. Over the past year, how much has your company invested on average in new services that rely on circular economy business models?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don't know/No answer

158. Is your company planning to use Circular Economy Business Models in the coming year?

- Yes
- No

If yes

159. In the next year, how much is your company planning to invest on average in Circular Economy Business Models?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don’t know/No answer

160. In your assessment, has the adoption of Circular Economy Business Models increased or decreased your productivity? Note: Productivity is proxied by the output per hour worked

- Increased
- Decreased
- No change

If increased

161. Could you please estimate the percentage increase in productivity? Note: Productivity is proxied by the output per hour worked. Insert as percentage e.g. 1%

If decreased

162. Could you please elaborate why

163. In your assessment, has the adoption of Biotechnology increased or decreased your production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc.

- Increased
- Decreased
- No change

If increased

164. Could you please estimate the percentage increase in production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labour and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc. Insert as percentage e.g. 1%

If decreased

165. Could you please elaborate why

CLEAN PRODUCTION TECHNOLOGIES

For all qualified companies; selecting clean production in Q13

166. Over the past year, how much has your company invested on average in clean production technologies?

- Nothing
- Less than €50,000
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don't know/No answer

167. Is your company planning to use clean production technologies in the coming year?

- Yes
- No

If yes

168. In the next year, how much is your company planning to invest on average in clean production technologies?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don’t know/No answer

169. In your assessment, has the adoption of clean production technologies increased or decreased your productivity? Note: Productivity is proxied by the output per hour worked

- Increased
- Decreased
- No change

If increased

170. Could you please estimate the percentage increase in productivity? Note: Productivity is proxied by the output per hour worked. Insert as percentage e.g. 1%

If decreased

171. Could you please elaborate why

172. In your assessment, has the adoption of clean production increased or decreased your production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc.

- Increased
- Decreased
- No change

If increased

173. Could you please estimate the percentage increase in production costs? Note: Production costs are expenses a company incurs to manufacture a product or provide a service. These costs include direct materials, direct labor and indirect costs such as rent, utilities (electricity, water, etc.), maintenance and repairs etc. Insert as percentage e.g. 1%

If decreased

174. Could you please elaborate why

For all qualified companies; selecting any of the answers in q8

Environmental services

175. Does your company offer any specific environmentally focused services for your customers (such as ecotourism services in the case of tourism, sustainable mobility in the case of automotive, product take back and refurbishment in the case of textiles or electronics, or similar for other industries etc)?

- Yes
- No

If yes

176. If yes, can you please specify what type of environmental services do you offer to your clients?

177. Has your company bought any environmental services over the past five years from third parties such as energy audit, carbon footprint analysis, water audit, environmental impact assessment, environment related consultancy, etc?

- Yes
- No

178. Does your company offer any specific services focusing on

- Local production
- Local consumption
- Short value chain

For all qualified companies; selecting any of the answers in q8

. Environmental actions

179. What is the share of organic materials that you use within your products/production?

- Zero (0%)
- Less than 5%
- From 5 to less than 20%
- From 20 to less than 50%
- From 50 to less than 75%
- 75% or more

180. What is the share of waste that you have repurposed (waste given a new use or function rather than being discarded)?

- Zero (0%)
- Less than 5%
- From 5 to less than 20%
- From 20 to less than 50%
- From 50 to less than 75%
- 75% or more

181. Over the past year, how much has your company invested on average in environmental technologies and measures (into your green transformation)?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don't know/No answer

182. In the next year, how much is your company planning to invest in environmental technologies and measures (into your green transformation)?

- Nothing
- Less than 1% of annual turnover
- 1-5% of annual turnover
- 6-10% of annual turnover
- 11-30% of annual turnover
- More than 30% of annual turnover
- Don't know/No answer

183. Have the benefits of circular service models outweighed the costs for your business (does it pay off)?

- Yes
- No

For all qualified companies; selecting any of the answers in q8

. Consumer demand

184. In your sector/market(s), do you believe there is a tangible shift in consumer preferences and purchasing (consumer demand) towards environmentally sustainable products/services?

- Yes
- No

If yes

185. If yes, please elaborate:

SKILLS

186. In your company, how many of your full-time employees, including yourself, work in digital jobs (responsible for the digitalisation or IT matters of the company) some or all of their time? Could you give an estimate?

- 1
- 2-5
- 6-10
- 11-50
- More than 50
- 0 (no digital or IT employees)

187. In your company, how many of your full-time employees, including yourself, work in jobs related specifically to advanced digital technologies (AI Engineer, Data Scientist, Data Architect, Cybersecurity Analyst, Cloud Solutions Architect, Blockchain Developer etc) some or all of their time? Could you give an estimate?

- 1
- 2-5
- 6-10
- 11-50
- More than 50
- 0 (no digital or IT employees)

188. In your company, how many of your full-time employees, including yourself, work in jobs relevant for environment protection, environmental sustainability, the green transition of your company some or all of the time?

- 1
- 2-5
- 6-10
- 11-50
- More than 50
- 0 (no full-time employees in jobs relevant for the environment)

189. In your company, have you created any new positions / job titles dedicated to advanced digital technologies (such as AI engineer, data science,) over the past five years?

- Yes
- No

Explain which job titles:

190. In your company, have you created any new positions / job titles dedicated to environmental sustainability over the past five years?

- Yes
- No

Explain which job titles:

191. How much time does it take you in general to hire the required digital profiles?

- Less than 1 month
- 1 to 3 months
- 3 to 6 months
- 6 to 12 months
- More than 12 months
- We are constantly hiring but struggle to fill these positions

192. How much time does it take you in general to hire the required environmental profiles?

- Less than 1 month
- 1 to 3 months
- 3 to 6 months
- 6 to 12 months
- More than 12 months
- We are constantly hiring but struggle to fill these positions

193. Which types of skills are the most difficult for your company to find qualified professionals in?

- Technical skills (e.g., engineering, programming, data analysis)
- Digital skills (e.g., AI, cybersecurity, cloud computing)
- Green skills (e.g., sustainability, energy efficiency, circular economy)
- Manufacturing & operational skills (e.g., production, quality control, automation)
- R&D and innovation skills (e.g., scientific research, product development)
- Soft skills (e.g., communication, teamwork, problem-solving)
- Leadership & management skills (e.g., strategic planning, project management)
- Regulatory & compliance skills (e.g., legal, safety, environmental regulations)
- Sales & marketing skills (e.g., business development, customer relations)
- Other (please specify)

194. How do you address skill shortages in your company?

- Training in-house
- Outsourcing
- Recruitment abroad

Other

195. Did you establish a collaboration with a startup offering advanced digital technology solutions over the past two years?

- Yes, if yes elaborate which specific technology and country
- No

196. Did you establish a collaboration with a startup offering environmental solutions over the past two years?

- Yes, if yes elaborate which specific technology and country
- No

197. If you would like to receive our report, please provide us with an email address where you would like to receive the summary of our survey results and the study. (Please note that your email address will not be associated in any way with the responses you provided in this survey)

Appendix E: LinkedIn representativeness analysis

Reflections on the suitability of LinkedIn

LinkedIn is the largest professional network platform with rich information like profile summary, job title, job description and field of study, which can be used for the identification of skilled professionals in advanced technologies. **It represents the single most comprehensive source currently available for the construction of technology-specific skills related indicators**.

Compared to highly resource intensive alternatives such as surveys it represents the most cost-effective alternative considering not just the cost of running the analysis once but also the potential to run the analysis at regular intervals and on demand (e.g. during and after the Covid-19 crisis). The use of LinkedIn gives practitioners the flexibility not only to define any combination of skills but to do so at the national, regional or even local level.

To leverage the potential of the database for the purpose of policy making the indicators derived from the data need to be corrected for the under or overrepresented groups in the population which can be done using post stratification techniques. The lack of representativeness for the population characteristics is expected when using Big Data databases and the objective, as in every statistically sound survey analysis, is to apply the right method to derive correct estimates of the population.

Considerations to be taken into account when using LinkedIn data include the following points:

- LinkedIn is a voluntary professional networking platform for which subscription is voluntary. This implies that registered users have chosen to sign up, leading to self-selection into the sample. Hence, as the selection process is not random but voluntary, the LinkedIn sample is not a random sample. Secondly, the self-selection of LinkedIn users implies that they chose to join based on rational arguments, and only those who find utility in joining will do so. This is likely to create bias as not everyone has the same utility of joining LinkedIn depending on various factors such as geographical location, sector of activity and plausibly level of education. This is supported by the data, as one can easily observe differences in popularity of LinkedIn between countries and sectors. Hence, self-selection of LinkedIn users justifies the expected lack of representativeness of the active population.
- Using the LinkedIn tool to harvest data is very powerful and provides practitioners the flexibility to monitor skills supply in a way that has not been possible using traditional data sources. It is based on the algorithm developed by LinkedIn. Access to the raw data for an extended verification of the results is not possible but it is possible to manually check the profiles returned by queries to assure the good performance of the queries. It should also be noted that for instance when looking for the share of population with specific skills, it is not possible to assess the level of the skill, nor to distinguish between academic knowledge and industry knowledge. However, skills supply in a specific industry are possible to isolate by selecting a sector which results in only professionals currently employed in the sector in focus to be returned by the query. Furthermore, the database is constructed based on the information provided by the users on their profiles. Users basically have the opportunity to claim what they want, although it would be unlikely that someone would claim a skill not at all relevant for the employment profile he/she is working in. Data is therefore dependent on users' honesty, self-assessment (what skills do I consider having?), willingness to share information and involvement in the network (how exhaustive is my profile?). This characteristic may leave room for non-accuracy of information but that would have been the same in the case of surveys.

Considerations to be taken into account when reading the representativeness analysis include:

- The LinkedIn database suffers from missing data points such as for instance the level of education. This does not compromise the indicators but rather the possibility to run a comprehensive representativeness analysis.
- Another limitation in performing a comprehensive representativeness analysis by comparing the LinkedIn database, with the data retrieved from Eurostat is that the two datasets have different origins and hence there are mismatches in the definition of some categories. For example, the educational attainment categories on LinkedIn (masters' degree; bachelor's degree; high school) are different from Eurostat (tertiary education; upper secondary and post-secondary non tertiary education; lower than primary, primary and lower secondary education). The same kind of mismatch exists for skills and sector. These differences affect the assessment of representativeness as the comparisons between the two datasets have to be made based on criteria that are not identical.

Approach to test the representativeness of LinkedIn

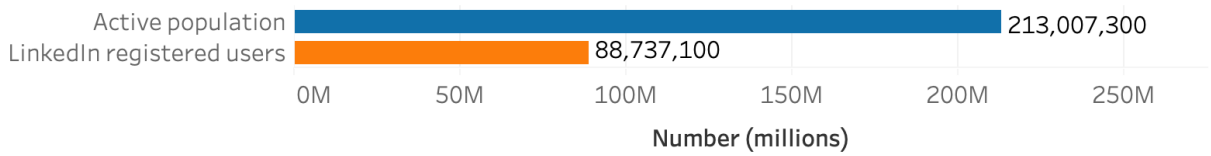
To perform the test of representativeness of LinkedIn we proceeded in two stages. First, the two datasets notably LinkedIn and Eurostat (active population) have been compared based on key statistics. These descriptive statistics show if the two populations behave similarly regarding different key aspects: entire workforce, educational attainment, gender and the science sector. Similar behaviours and figures tend to indicate that the sample represents well the population. Second, the representativeness of LinkedIn has been statistically tested on the same aspects through X-squared tests. These tests allow to check whether the difference in the behaviour of the two populations is statistically significant or not, and therefore whether the sample fail to represent the population, or not.

Descriptive statistics comparing Eurostat data and LinkedIn aggregates

Workforce

The comparison of the EU27 workforce and the number of EU27 LinkedIn users in terms of absolute numbers shows that the active population of the EU27 is 213 million while 88.7 million Europeans are registered on LinkedIn. In other words, 41.6% of the active population is registered on the professional networking platform.

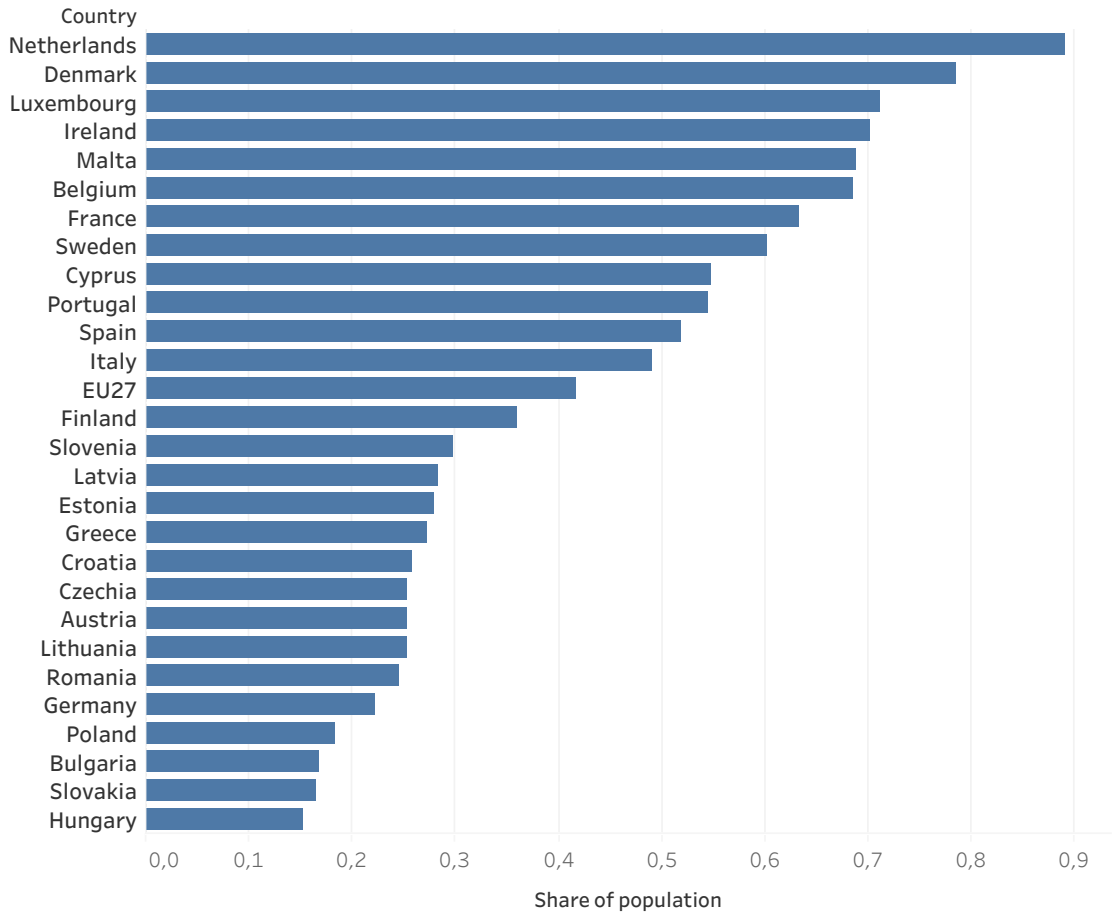
Figure 15: EU27 active population vs EU27 LinkedIn registered users



Source: LinkedIn and Eurostat (Active population by sex, age and educational attainment [lfsa_agaed] - All ISCED 2011 levels; 15 to 74 years old; 2018)

Behind the aggregated figure at the EU27 level, there is an important heterogeneity in the national use of LinkedIn among EU Member States, as indicated by the next figure. Indeed, in some EU countries, the number of LinkedIn users is marginal, while it is widely spread in others. In particular, Hungary, Slovakia, Bulgaria and Poland display the lowest use of LinkedIn, with less than 20% of the population registered on the platform. On the other hand, Netherlands and Denmark are the countries where LinkedIn is the most popular, with more than 75% of the active population registered (see Figure on the next page).

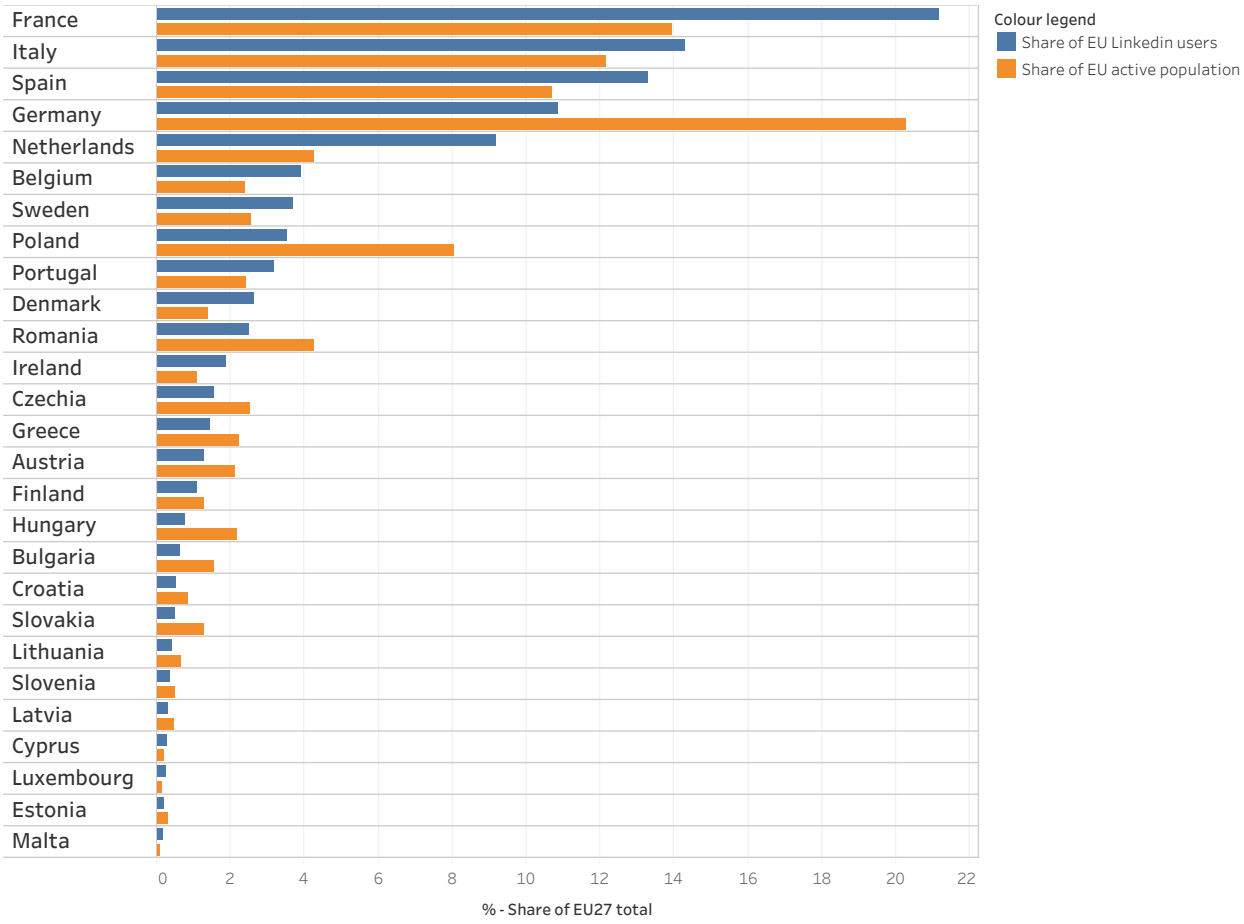
Figure 16: Share of active population registered on LinkedIn by country



Source: LinkedIn and Eurostat (Active population by sex, age and educational attainment [lfsa_agaed] - All ISCED 2011 levels; 15 to 74 years old; 2018)

As a result of the heterogeneity in the use of LinkedIn between EU Member States, the LinkedIn population does not reflect the EU population. Indeed, the countries where the use of LinkedIn is rare are underrepresented on the platform, while the countries where the use of LinkedIn is widespread are overrepresented. Figure 10 compares the share of the EU workforce and of the EU LinkedIn population of each country, and highlights the mismatch between them. For example, while the active population of Poland and Romania accounts for 8.03% and 4.25% of the total EU active population respectively, they only represent 3.53% and 2.5% of the EU LinkedIn users. On the contrary, Netherlands and Denmark represent 9.16% and 2.64% of the LinkedIn users although they only account for 4.28% and 1.4% of the EU active population. In total, 15 countries are underrepresented on LinkedIn (e.g. Germany) and 12 are overrepresented (e.g. France).

Figure 17: Share of total EU 27 active population vs share of total EU LinkedIn users by country



Source: LinkedIn and Eurostat (Active population by sex, age and educational attainment [lfsa_agaed] - All ISCED 2011 levels; 15 to 74 years old; 2018)

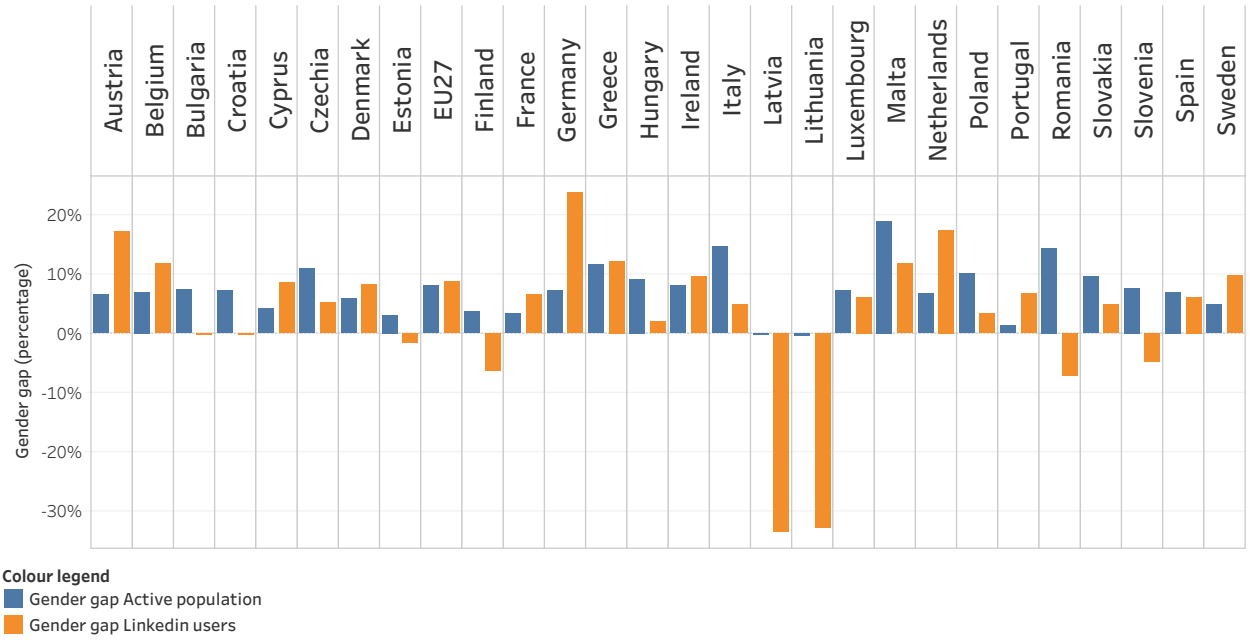
Gender

In order to assess the representativeness of the LinkedIn population in terms of gender proportions, we use the gender gap.[53] Figure below illustrates the gender gap that takes place in the active population and among the LinkedIn registered users. At the EU level, the gender gap on LinkedIn is comparable to the gender gap in the active population, with respective values of 8.62% and 7.95%. Regarding gender proportions, the LinkedIn population is therefore representative of the active population at the European level. However, among EU Member States, heterogeneity is observed.

Some countries display higher gender gaps on LinkedIn than in the active population. In particular, Austria, Germany and Netherlands display the most important gender gap on LinkedIn despite a limited gender gap in the active population. On the contrary, there are countries where the gender gap is reduced on LinkedIn compared to the active population, or even of opposite sign. Indeed, Estonia, Finland, Slovenia and Romania have a negative gender gap on LinkedIn (more women than men) but a positive one in the active population. This indicates a high propensity of women to register on LinkedIn. The same trend occurs in Lithuania and Latvia where the gender gap is negative both among the LinkedIn users and the active population, but is more pronounced on LinkedIn.

[53] The gender gap is calculated as the difference between the percentage of the labour market constituted of men and the percentage of the labour market constituted of women. The classification used in the case of the gender gap is therefore the same as the presence of women on the labour market.

Figure 18: Gender gap in active population vs LinkedIn users

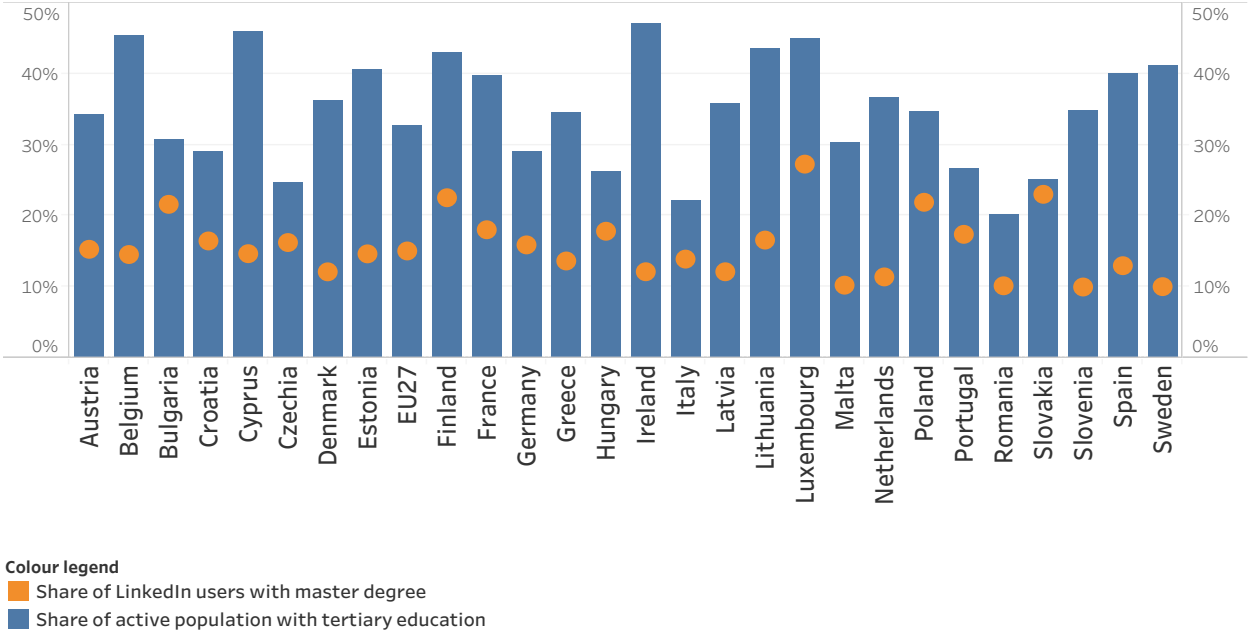


Source: LinkedIn and Eurostat (Active population by sex, age and educational attainment [lfsa_agaed] - All ISCED 2011 levels; Females and Males; 15 to 74 years old; 2018)

Educational attainment

Regarding the educational attainment, we first analysed the highest educated share of population both in LinkedIn and in Eurostat data. When comparing the share of LinkedIn users with master's degree and the share of active population with tertiary education, one can observe that the share of population with tertiary education is smaller for the LinkedIn users than for the active population in all countries. The first straightforward explanation is the underrepresentation of the population with a master's degree among LinkedIn users. However, more plausibly, the low shares of tertiary educated workers on LinkedIn might as well be explained by the non-systematic registration of educational attainment on LinkedIn. Since the information on the educational attainment is missing for 68.7% of the LinkedIn sample, the share of those who are registered as having a master on the total users is low. Additionally, only the LinkedIn users having a master's degree are accounted for in the LinkedIn ratio, while tertiary education includes other forms of higher education in the active population ratio.

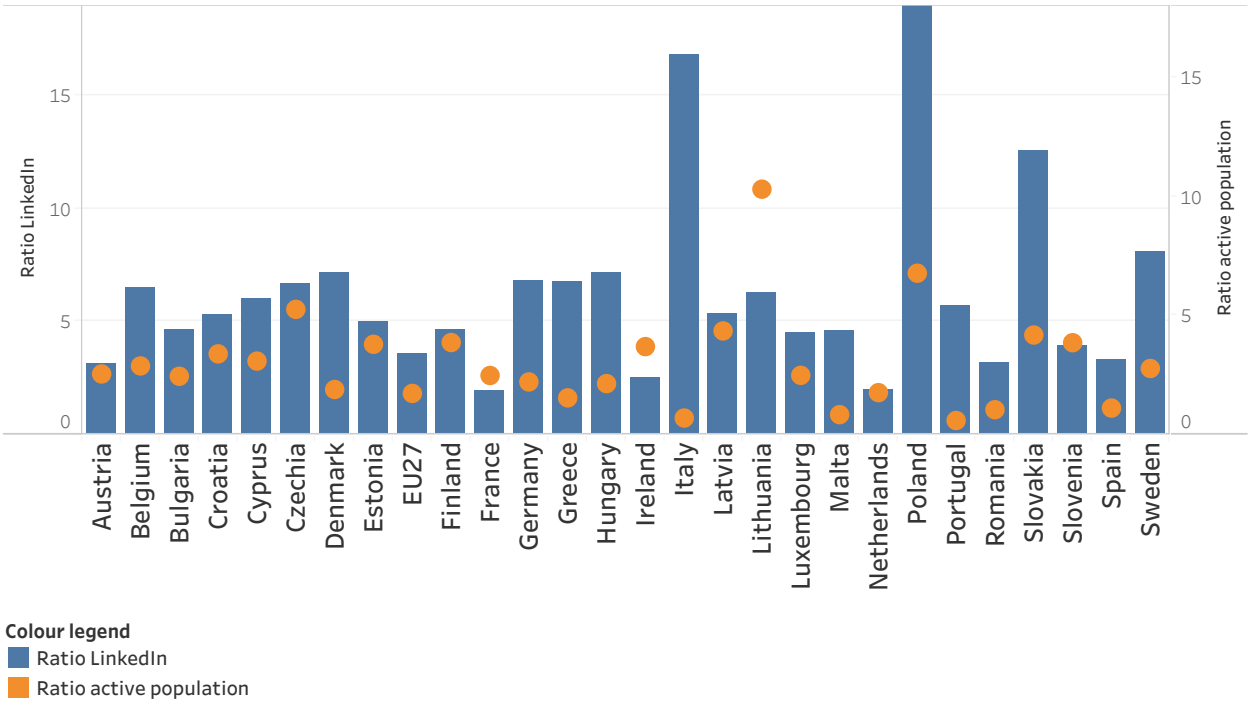
Figure 19: Share of highest educated among LinkedIn users vs active population



Source: LinkedIn and Eurostat (Active population by sex, age and educational attainment [lfsa_agaed] – ISCED 2011 Levels 5-8; 15 to 74 years old; 2018)

In order to avoid the bias caused by the missing information on educational attainment, we use a ratio for the active population and for the LinkedIn population. The structure of the ratio takes into account both extremes of the education distribution and it is constructed in the following way. The share of people with highest educational attainment (master's degree for the LinkedIn users, tertiary education for the active population) on the share of people with the lowest educational attainment (high school for LinkedIn users and less than primary, primary and lower secondary education for active population). Comparing both ratios allows to see if the proportions between highly educated and low educated are similar in the two populations without being distorted by the missing information. From Figure below one can observe that in most countries (19 EU Member States and EU27 average), the ratio of the highest educated on the lowest educated is higher among LinkedIn users than in the active population. In other words, among the LinkedIn users for whom the educational attainment is available, the highly educated (master's degree) are overrepresented. This is particularly true for Italy, Portugal and Poland where the difference between the LinkedIn ratio and the active population ratio is the largest. In fact, the ratio for Poland is so high that it is not fully visible on Figure 20 (57.4). It is interesting to note that in the case of Italy and Portugal, the important difference between the two ratios is linked to the large share of the active population with the lowest educational attainment. It can be deducted that while this fringe of population reduces the active population ratio, it does not have the same effect on the LinkedIn ratio because it is not present among LinkedIn users, i.e. underrepresented in the LinkedIn population.

Figure 20: Educational attainment ratio among LinkedIn users vs in active population



Source: LinkedIn and Eurostat (Active population by sex, age and educational attainment [lfsa_agaed] – ISCED 2011 Levels 0-2 & 5-8; 15 to 74 years old; 2018)

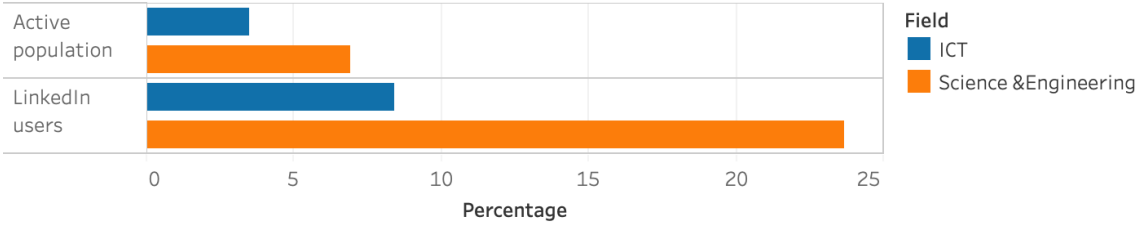
There are few cases where the active population ratio is more important than the LinkedIn ratio, but the difference is generally quite small (<1.5). The only exception is Lithuania, where the difference of ratio therefore indicates that on LinkedIn the lowest educated are overrepresented and/or the highest educated underrepresented.

In general, the lowest educated are underrepresented and/or the highest educated are overrepresented in most of the EU Member States (including EU27 average). In terms of educational attainment, the LinkedIn population is not representative of the active population.

Science & Engineering and ICT

The representativeness of the LinkedIn sample can also be assessed against the importance of different knowledge activities among the population. We compare the relative importance of the Information and Communications Technology population (ICT) and the Science and Engineering population (SE). In Figure 21 the number of people working in ICT and SE is taken as the percentage of the active population and of the LinkedIn users. 6.92% of the active population works in SE[54] and 3.49% in ICT[55], while 23.68% of LinkedIn users are from the SE sector and 8.38% from the ICT sector.

Figure 21: Share of EU active population vs share of EU LinkedIn users in Science & Engineering vs in ICT



Source: LinkedIn and Eurostat (A. *Active population by sex, age and educational attainment [lfsa_agaed] - All ISCED 2011 levels; 15 to 74 years old; 2018.* B. Employed ICT specialists by sex [isoc_sks_itsps] – Males and Females; 2018. C. HRST by category, sex and age [hrst_st_ncat] – 15-74 years old; Scientists and engineers; 2018)

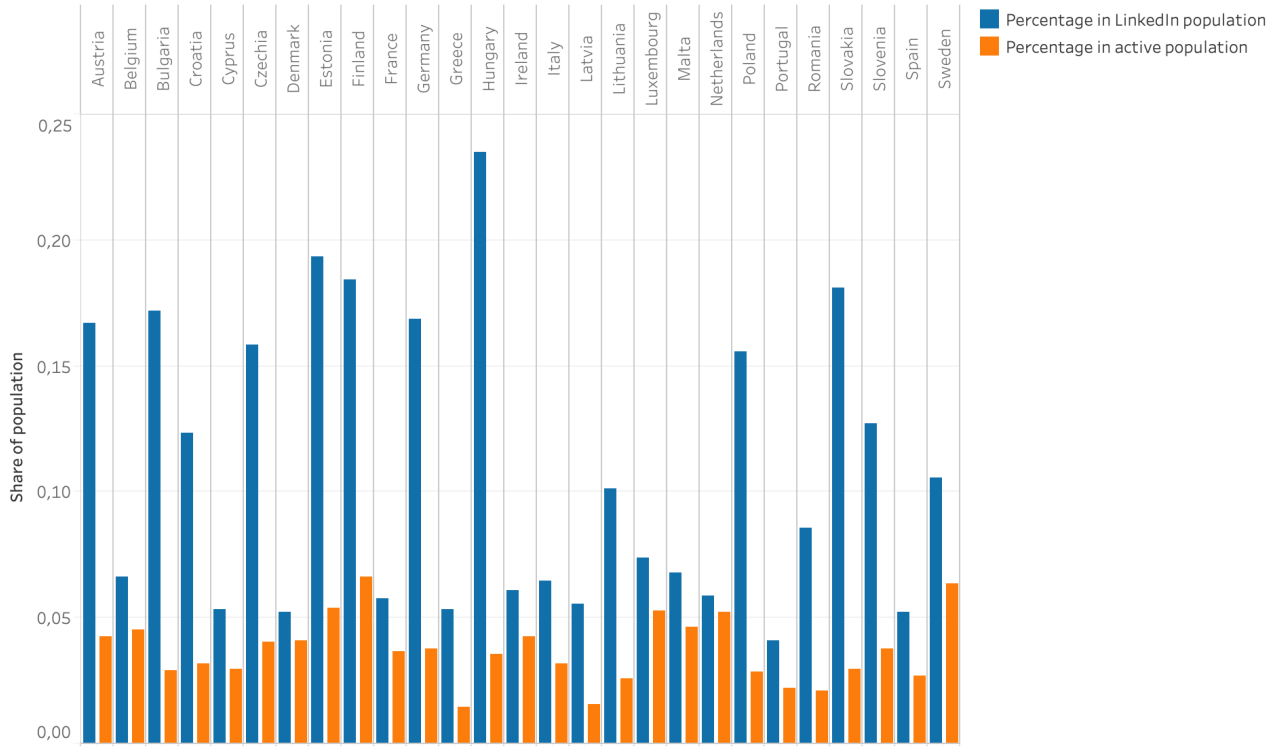
One can observe that both populations are overrepresented on LinkedIn, as they represent a larger share in the LinkedIn population than in the active population. This trend is even more pronounced for the SE sector: the share of LinkedIn users in SE is more than 3 times more important than the share of active population in SE. For the ICT sector, this figure is around 2.4. The overrepresentation of the ICT and SE sectors on LinkedIn does not only concern the EU27 as a whole, but it is persistent among all EU Member States. In all countries the share of population in ICT and SE is higher among the LinkedIn users than in the active population.

However, this trend occurs to different extents. In particular, Hungary has among the largest gaps for both ICT and SE, along with Finland for SE and Bulgaria, Estonia and Slovakia for ICT. Ireland and Luxembourg are interesting cases because the gaps between the share of LinkedIn population in SE and the share of active population in SE are among the largest; while in ICT this gap is very limited. The best performers in terms of representativeness of the LinkedIn sample, i.e. the EU Member States with the smallest gap between the LinkedIn population and the active population, are Romania, Poland and Sweden for SE, Denmark and Portugal for ICT and Belgium and Netherlands in total.

[54] Eurostat: HRST by category, sex and age [hrst_st_ncat]; Active population by sex, age and educational attainment [lfsa_agaed]

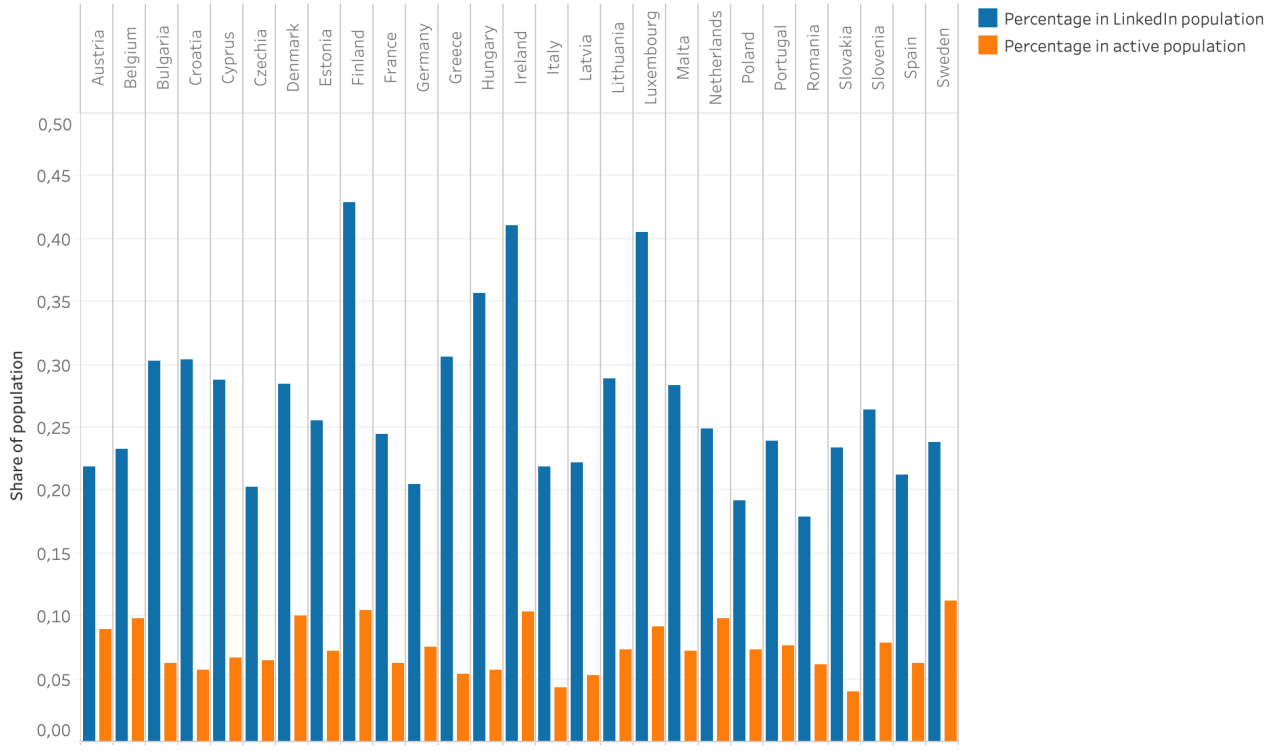
[55] Eurostat: Employed ICT specialists by sex [isoc_sks_itsps]; Active population by sex, age and educational attainment [lfsa_agaed]

Figure 22: Share of LinkedIn users in ICT vs share of active population in ICT by country



Source: LinkedIn and Eurostat (A. *Active population by sex, age and educational attainment [lfsa_agaed] - All ISCED 2011 levels; 15 to 74 years old; 2018.* B. Employed ICT specialists by sex [isoc_sks_itsps] – Males and Females; 2018)

Figure 23: Share of LinkedIn users in Science and Engineering population vs share of active population in Science and Engineering population by country



Source: LinkedIn and Eurostat (A. *Active population by sex, age and educational attainment [lfsa_agaed] - All ISCED 2011 levels; 15 to 74 years old; 2018.* B. HRST by category, sex and age [hrst_st_ncat] – 15-74 years old; Scientists and engineers; 2018)

Despite these few exceptions, the population in Science & Engineering and ICT is in general largely overrepresented on LinkedIn. Hence, regarding the knowledge activities, the LinkedIn population is not representative of the active population.

In conclusion, as anticipated, LinkedIn based indicators will need to be corrected to reflect the distribution of the population for the characteristics in focus. This is because LinkedIn's popularity is different from a country to another, causing the EU Member States where it is more widespread to be overrepresented. Moreover, there is a misrepresentation of the educational attainment as the ratio between the highest educated and the lowest educated is considerably more important on LinkedIn than in the active population. Similarly, the prevalence of LinkedIn depends on the knowledge activity. The population in Science & Engineering is overrepresented, as well as the Information & Communication Technology population to a lesser extent. The weighting mechanism to correct for the lack of representativeness is described in section **Error! Reference source not found.**.

Statistical testing

Beyond the comparison of the LinkedIn population and the active population in terms of descriptive statistics, the representativeness of LinkedIn has been also assessed through statistical testing. The X-squared tests compare the observed frequencies (i.e. derived from the LinkedIn population) and the expected frequencies (i.e. derived from the active population) and assess if the difference between them is statistically significant or not. In other words, they test if the frequencies correspond to the same population or if, on the contrary, the LinkedIn sample is not representative of the active population.

We perform the X-squared tests[56] with regard to the importance of the national workforce, the population's educational attainment, the gender proportions and the prevalence of ICT and SE. Each test has been run for the EU27 and by country (apart from the national workforce which is obviously not tested at the level of EU27). The tests are unequivocal as they all display the same result: the LinkedIn population is not representative of the active population.[57]

Comparison of LinkedIn population in the EU27 and the US

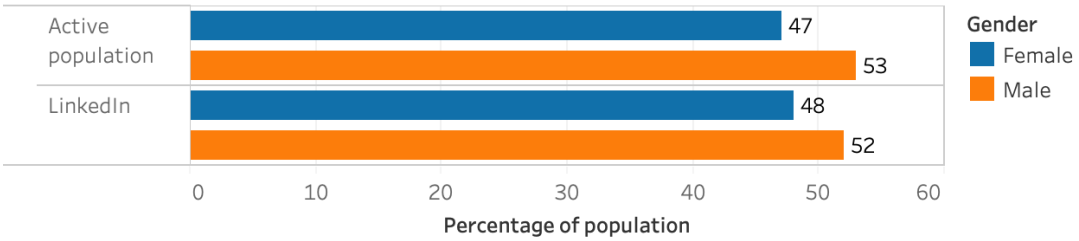
The networking platform LinkedIn is more popular in the United States than in the EU27, as 164.98 million Americans are registered on LinkedIn, i.e. 100.88% of the US active population, against 41.6% in the EU27. In fact, the US even has more nationals registered on LinkedIn than accounted in the active population (as indicated by the percentage greater than 100). This is very likely to be due to the use of LinkedIn among non-active parts of the population, such as students and retirees. Given the prevalence of LinkedIn in the US, it is of interest to assess its representativeness, and to compare it with EU27.

In order to analyse the representativeness in terms of gender, we compare the proportions of males and females in the labour force and in the LinkedIn population. As indicated by the Figure below, the active population in the US is composed of 53% of males and 47% of women, against 52% and 48% on LinkedIn. The figures are therefore similar, even if the gender gap is slightly reduced on LinkedIn, going from 6% in the labour force to 4%.

Figure 24: Gender proportions in the US active population vs among the US LinkedIn users

[56] The X-squared tests are run with the statistical software STATA.

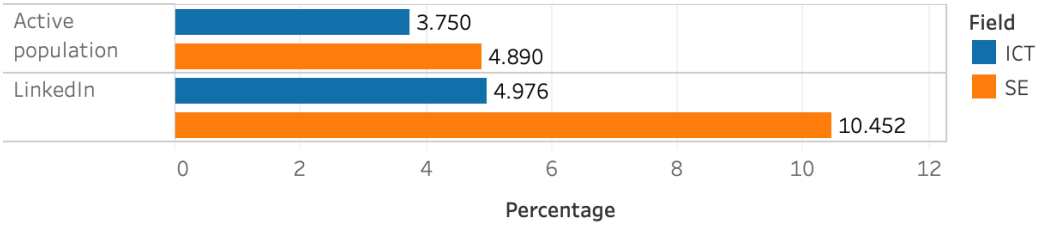
[57] The X-squared tests reject the null hypothesis of representativeness.



Source: LinkedIn 2020 and OECD 2019 (OECD Data – Labour force)

As it was the case in the EU27, some knowledge activities are overrepresented on LinkedIn. Figure 25 shows that the shares of the LinkedIn population in the ICT and SE sectors are larger than the corresponding shares in the active population. However, this trend occurs to a lesser extent than in the EU27. In particular, the share of the LinkedIn users in the ICT sector is 'only' 33% larger than the share of the active population in ICT. For the SE sector, the LinkedIn share is 2.14 more important than the active population share, indicating a pronounced overrepresentation of the SE population on LinkedIn, although still smaller than for EU27.

Figure 25: Share of US active population vs share of US LinkedIn users in Science & Engineering vs in ICT



Source: LinkedIn 2020, National Science Foundation 2018 (Individuals in S&E occupations as a percentage of all occupations – USA; 2018), OECD 2017 (OECD Digital Outlook 2017 - Share of ICT specialist employment; 2014)