European Commission

Monitoring the twin transition of industrial ecosystems

CONSTRUCTION

Analytical report

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Executive summary

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

The construction industrial ecosystem is a key industrial ecosystem for Europe. Overall, the value-added of the construction ecosystem was €1 208 bn (9.6% of the EU total) in 2019 with a total of 25.4 million persons employed, the majority of which in the construction sector itself. The ecosystem is largely dominated by small and medium-sized enterprises (SMEs), with 75.5% of workers employed by an SME, of which 36.5% are companies with 0-9 persons.

The construction industry is typically considered a **traditional and low-tech industry with a high environmental impact both in terms of energy consumption and greenhouse gas emissions (GHG), as well as materials and resource needs and waste generation**. At the same time, the construction industrial ecosystem is faced with further challenges that require technological and industry response, including among others climate change and GHG emissions and demographic change, as well as recycling and recovery to name a few.

The **green transition in construction** is driven by the need to reduce the environmental impact of the construction industry by both improving energy and material efficiency and recyclability. This is apparent from the use of green technologies such as energy saving technologies, renewable energies, advanced materials, and recycling technologies. **Digitalisation, with technologies such as Building Information Modelling (BIM),** are an essential element to improve efficiency and circularity in construction and develop a more efficient management of resources and of the built environment, showcasing the interplay of the twin transition. At the same time, digitalisation allows to improve the efficiency of design and planning stages of construction projects in term of human resource required but also project execution. In the area of digital technologies, advanced manufacturing and robotics, artificial intelligence, augmented and virtual reality, big data and cloud computing, blockchain, and internet of things play a key role.

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

Key findings about the green transition

The green transition is tightly linked to the capabilities of the industrial ecosystem **to improve energy and material efficiency and to enhance circularity**. Patent applications in the construction industry are used in general to protect an innovative feature of a new building, structure or component for instance related to alternative construction methodologies or green building. **Patents in green technologies** in construction typically number over 400 per year in the EU27 from 2010 to 2020. **Advanced sustainable materials and air and water pollution reduction technologies** are leading with a 25.6% and 17.85% share. **Solar photovoltaics and wind** related technologies have been patented the most among the renewable energy technologies.

Green construction tech startups are active in the field of energy (including energy efficiency, renewable energies, energy saving), followed by recycling technologies and other green building solutions. Energy, amongst which energy saving technologies and renewable energy are the most dominant focal areas in the green transition for the construction tech startups. The focal areas therein include the development of solutions for homes in residential settings but also for businesses.

Results of a **large-scale business survey** highlight that 38% of the SMEs in the construction industrial ecosystem report making investments in the green transition and environmental sustainability in the last five years. Annual investments were less than 15% in the case of the half of the respondents. SMEs in the construction industrial ecosystem switched to the use of **energy saving technologies** with a share of 23% adopting this green solution. This finding is not a surprise since energy-saving has become very important since the start of soaring energy prices in 2021. While **recycled materials** are the second solution adopted by SMEs, at 22%, 77% of the respondents declare that they use or plan to use less than 20% of recycled materials. Further solutions adopted include recycling technology and solutions as well as **renewable energies** both indicated by 20% of the respondents.

Investments made through public spending, specifically **procurement** by public authorities are particularly interesting as a data source for construction due to considerable public spending on construction. As a result of the analysis, public procurement on construction was valued at a total of over €825 bn between 2015 and 2020, with 0.82% of the total procurement value dedicated to the green transition, with the green transition accounting for 4% of the noticed published. **Energy performance, material re-use and the use of photovoltaics** made up the most common references underpinning this transition in the construction industrial ecosystem. Specifically, energy performance is outlined among the evaluation and award criteria, where contractors need to demonstrate previous experience in designing or building a building that has obtained high energy performance certificate ratings. Reuse of materials are typically included as a specification of the materials to be used for construction, whereas photovoltaics is generally mentioned as part of specific solar power projects.

Key findings about the digital transition

Technological shifts in the construction industry are driven by the need for digital, future proof industry that responds to current needs. **Digital construction tech startups** are active in **three main technological areas relevant for the digital transition, namely in the provision of software solutions, advanced digital technologies and advanced manufacturing**. Software solutions are leading the way, with analytical software, Building Information Modelling (BIM), and 3D visualisation as a part of the overall group. Within the advanced digital technologies, Internet of Things (IoT) and Artificial Intelligence (AI) are particularly important. Advanced manufacturing consists of additive manufacturing (3D printing) as well as robotics and modular production. The latter, while making up the smallest fraction, presents several technological solutions that actively address specific challenges faced by the construction industry such as the labour shortage as well as the housing crises through modular production.

Digital skills have been defined in the context of the main digital technologies captured in this project notably in artificial intelligence, cloud computing, connectivity, robotics, Internet of Things, augmented and virtual reality and blockchain. Based on the analysis of LinkedIn data, 18% of the professionals working within the construction industrial ecosystem and with a profile on LinkedIn reported at least one digital skill. **Among the supply of professionals with specific digital skills within the construction industrial ecosystem in 2022, advanced manufacturing and BIM stand out.**

Investments in innovative digital construction tech companies lie predominantly in the areas of analytical software services (data, cloud etc), as well as **online marketplaces** and **Internet of Things and smart building** with over €390 m, €215 m, €137 m in investments, respectively. It is also worth noting that BIM, digital twin, and augmented and virtual reality (AVR) including 3D visualisation tools received €110 m over the period from 2010 to 2022.

Regarding R&D&I investments EU27 companies are focussing more on digital technology investment in the construction ecosystem with over €1.8 bn in investments from 2017-2021. That being said, the EU27 is showing declining trends, especially for digital technologies. Looking at the total R&D&I investments across the EU-27, China, South Korea, Japan and the US over the period of 2017-2021, **additive and robotic manufacturing, BIM-compatible plug-ins and applications/4D BIM**, as well as **digital twins** stand out as being of global importance for the observed regions for the construction industrial ecosystem.

1. Introduction

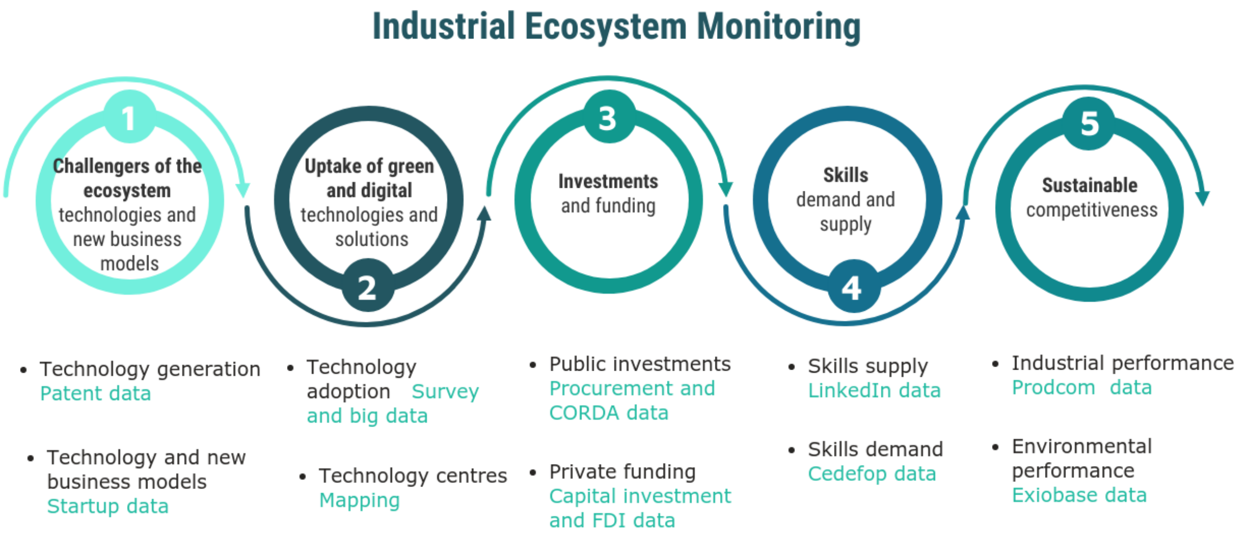
1.1. Objectives

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

The EU's updated industrial strategy[1] has identified 14 industrial ecosystems[2] – one of them being 'Construction' - that is in the focus of this report. The industrial strategy defined industrial ecosystems as encompassing all players operating in a value chain: from the smallest startups to the largest companies, from academia to research, service providers to suppliers. The notion of ecosystems captures the complex set of interlinkages and interdependencies among sectors and firms across the EU. Industrial transition is driven by technological, economic, and social changes, and in particular by green and digital technologies and the shift to the circular economy. The process is however characterised by complex, multi-level, and dynamic development. To make transition sustainable, technological change needs to be coupled with new business models, the necessary investments, skills, regulatory framework conditions and behavioural change across the ecosystem.

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

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



Source: Technopolis Group, IDEA Consult and Fraunhofer ISI

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

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

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

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

Figure 2: Main technologies monitored in the project

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

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

Source: Technopolis Group, IDEA Consult and Fraunhofer ISI

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

1.2. Definition of the ecosystem

As a matter of positioning a few key definitions are presented, including the distinction between the 'construction industry', the 'construction industrial ecosystem' and the 'transition pathway for construction', as presented in Figure 3. The 'construction industry' refers in the narrow sense to the activities of the construction industry as it is formulated in e.g., the statistical classification of economic activities (specifically NACE F). For the purpose of this study and report, we focus on the 'construction industrial ecosystem' as it is outlined in the Industrial Strategy and Annual Single Market Report. [4] Furthermore, going a step further this report focuses on the transition pathway for construction, zooming in on the green and digital transition as well as resilience within the construction industrial ecosystem.

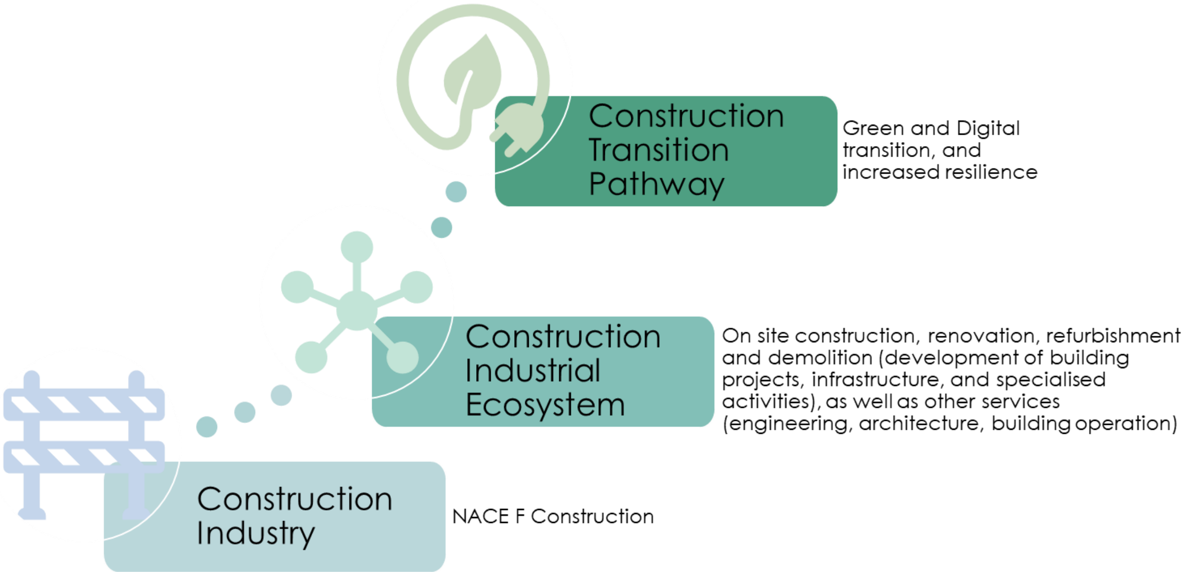
According to the European Commission Annual Single Market Report (2021), the **construction industrial ecosystem** covers "*contractors for building and infrastructure projects, some construction product manufacturers, engineering and architectural services*

[3] https://ec.europa.eu/docsroom/documents/49407/attachments/1/translations/en/renditions/native
[4] European Commission (2021) Annual Single Market Report

as well as a range of other economic activities (e.g., rental and leasing of machinery and equipment, employment agencies)".[5] *It covers the design, construction, maintenance, refurbishment, and demolition of buildings and infrastructure (e.g., transport infrastructure).* In terms of NACE classification, this translates into:

- Manufacture of furniture (C31)
- Construction (F)
- Architectural and engineering activities; technical testing and analysis (M71)
- Services to buildings and landscape activities (N81)[6]

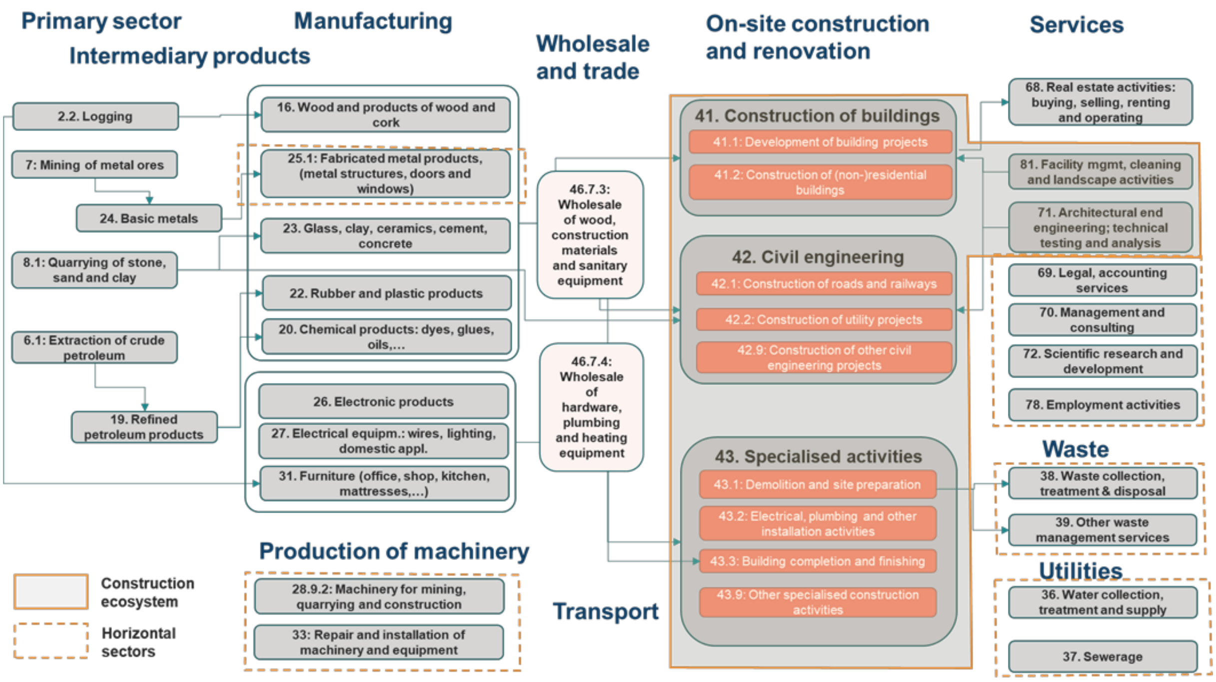
Figure 3: Positioning construction industrial ecosystem definitions



Source: IDEA Consult based on the definition of the construction ecosystem as described in the Annual Single Market Report 2021

[5] European Commission (2021). Annual Single Market Report
[6] European Commission (2022). Annual Single Market Report

Figure 4: The construction ecosystem within the construction value chain[7] [8]



Source: European Commission, 2021

Figure 4 delineates within the **construction value chain** the activities of the construction industrial ecosystem (as outlined by the orange line), which include:

- Construction of building
- Civil engineering
- Specialised activities
- Facility management, cleaning, and landscaping activities
- Architectural, engineering, technical testing, and analysis services.

In addition, a series of horizontal sectors are outlined to be considered fractionally a part of the industrial ecosystem, including production of construction related machinery, legal, consulting and scientific services as well as waste and utilities. For the purpose of this report, the construction ecosystem forms the basis of the construction ecosystem delineation.

1.3. State of the industry

The construction industrial ecosystem is a key industrial ecosystem for Europe. Overall, the value-added of the construction ecosystem was €1 208 bn (9.6% of the EU total) in 2019 with a total of 25.4 million persons employed, the majority of which in the construction sector itself (NACE F).[9] In terms of company size, 36.5% of the construction industrial ecosystem workers are employed in companies with 0-9 persons, with 75.5% employed by an SME. Overall, 71.2% of the value added of the construction industrial

[7] European Commission (2021) SWD Scenarios for a transition pathway for a resilient, greener and more digital construction ecosystem
[8] Furniture is included in the scope of the industrial ecosystem.
[9] European Commission (2022) Annual Single Market Report

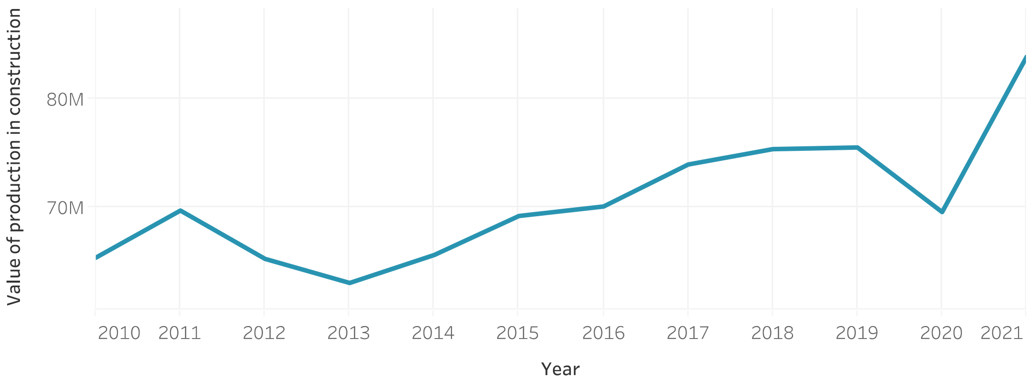
ecosystem comes from SMEs in 2019. This translates into over 5.3 million firms forming the construction industrial ecosystem in the EU in 2018. [10]

Production performance of the construction industrial ecosystem can be represented in many different ways and can give insight into the economic performance of the sector or ecosystem depending on the dataset in question. When available across time series, production performance allows to position the overall evolution of the sector or industrial ecosystem.

Production volume is an indicator prepared by Eurostat in the form of the Construction production (volume) index[11], referring specifically to the NACE F Construction sector. Between July 2020 and July 2021, production volume increased by 3.3% in the euro area and 3.8% in the EU, bringing the overall volume within the range of pre-pandemic values.[12] Member states with the highest increase in production volume from 2020 to 2021 are Hungary, Austria and Sweden, whereas Spain, Slovenia and Belgium recorded the highest decreases over the observed time period.

The **total production value for the construction industrial ecosystem gives insight into the production performance of the overall ecosystem**. Data on production were extracted from Eurostat.[13] Prodcom statistics reveal the total values of production of manufactured goods carried out by enterprises located in EU27 over 14 years (from 2008 until 2021). The construction industrial ecosystem is delineated by the NACE 2 classification and weights identified in the Annual Single Market Report.[14] Results (Figure 5) present the weighted sum of production of manufactured goods aggregated at NACE 2-digit level for the construction industrial ecosystem (thousands of euros).

Figure 5: Production performance of construction industrial ecosystem for the EU 27 in EUR thousands for 2008-2021



Source: IDEA Consult based on Eurostat [prom]

Economic crises such as in the global financial crisis are visible, mainly impacting the construction industrial ecosystem in 2009. The COVID-19 pandemic in 2020 also clearly stands out with recovery in production performance in 2021, which is also reflected in the perceived recovery of the ecosystem overall after the pandemic. **A positive trend in production value from 2013 onwards** (with the exception of 2020) **is nevertheless clearly evident**.

The COVID-19 crisis particularly impacted the construction industrial ecosystem as works came to stop in 2020, with lockdowns restricting access of workers to homes, but also manufacturing activities were reduced or stopped altogether to limit the spread of the

[10] European Commission (2022) Annual Single Market Report based on Structural Business Statistics
[11] Eurostat (2023) Construction production (volume) index overview, see: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Construction_production_(volume)_index_overview
[12] Eurostat (2021) Production in construction see: https://ec.europa.eu/eurostat/documents/2995521/11563279/4-17092021-BP-EN.pdf/edff43b7-5ef5-01c8-2cf8-f572825bab56?t=1631867055642
[13] Eurostat Prodcom https://ec.europa.eu/eurostat/web/prodcom/data/database
[14] European Commission (2021) Annual Single Market Report

virus in the workplace.[15] This, in turn caused ruptures along supply chains. Coupled with transportation and logistics challenges related either to workers not being allowed to work due to lockdown restrictions or unable to work due to illness from the virus, supply chain challenges were further hampered by the limited ability to transport materials. As a result, the COVID-19 pandemic caused a decline in turnover in the construction sector (5% loss in 2020 compared to 2019).[16] That being said, the building construction market was able to successfully restart activities in 2021, and recovery is assumed to have taken place at the end of 2021.[17] The global construction market was valued at €6.85 trillion in 2021 (7.3 trillion USD)[18] and is expected to grow to the size of €13.52 trillion (14.4 trillion USD) by 2030.[19] The global construction market forecast showcases the recovery post-pandemic, but also, after the rapid incline post crisis, an expected slowing of the growth of the construction market at the global scale from 2023 onwards.

Challenges for the industry

The construction industry is typically considered a traditional and low-tech industry with a high environmental impact both in terms of energy consumption and greenhouse gas emissions (GHG), as well as materials and resource needs and waste generation.[20] Historically, the adoption of advanced technologies has been perceived as limited compared to the industry in general. The micro and small and medium-sized enterprises that dominate the industry do not always have the margins for investments in new, innovative technologies. Taking these contextual elements into consideration, the construction industry is faced with further challenges that require technological and industry response, including among others climate change and GHG emissions and demographic change, as well as recycling and recovery to name a few.[21]

Climate change is a particular challenge facing the construction industry, particularly related to the energy consumption of buildings in their operation. Buildings account for 40% of energy consumption and 36% of greenhouse gas emissions.[22] Construction designs that take into account the need for energy efficiency, have a huge potential to reduce CO_2 emissions, but also improve cost savings related to energy consumption, which is also an important consideration in the face of potential energy crises. However, these designs are also costly to implement, hampering their uptake. Low renovation rates (around 1%) are further hampering the potential for energy consumption reduction.[23] [24]

Construction and demolition waste accounts for 37.5% waste generated in the EU in 2020 by mass[25] and is as such the largest source of waste in Europe. While recovery rates are reportedly high, these include also backfilling and low value recycling.[26] [27] Due to the sheer volume and weight of the materials, transportation is limited for certain construction and

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[15] Allied Market Research (2022) Building Construction Market https://www.alliedmarketresearch.com/building-construction-market-A17012

[16] European Commission (2021) Scenarios for a transition pathway for a resilient, greener and more digital construction ecosystem.

[17] Allied Market Research (2022) Building Construction Market https://www.alliedmarketresearch.com/building-construction-market-A17012

[18] Exchange rate 5 March 2023 1 USD = 0.94 EUR

[19] Statista (2023) Size of the global construction market from 2020 to 2021, with forecasts from 2022 to 2030, https://www.statista.com/statistics/1290105/global-construction-market-size-with-forecasts/

[20] European Commission (2023) Transition pathway for Construction

[21] European Construction Technology Platform (ECTP) (2019). Strategic Research & Innovation Agenda 2021-2027 https://www.ectp.org/fileadmin/user_upload/documents/ECTP/Miscellaneous_doc/ECTP_SRIA_FINAL_20-11-2019.pdf

[22] European Commission (2021) Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the energy performance of buildings (recast) https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52021PC0802&from=EN

[23] Renovation Wave communication COM(202) 662 final. https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en

[24] European Commission (2023) Transition pathway for Construction

[25] Eurostat, 2020. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics#Total_waste_generation

[26] For further details on the definition of backfilling, please consult Guidance on the interpretation of the term backfilling https://ec.europa.eu/eurostat/documents/342366/4953052/Guidance-on-Backfilling.pdf/c18d330c-97f2-4f8c-badd-ba446491b47e

[27] European Commission (2021) Study on circular economy principles for buildings' design

demolition waste streams. Specialised materials have a greater potential for higher value recycling or reuse, such as bricks, and transportation radii are also higher. Business models for CDW recycling and the underlying technologies rely on the local market, including consumer demand for recycled products as well as the legislative framework in place.[28]

The construction industry is challenged by making multifunctional, multigenerational buildings of the future, that can meet the growing demand in urban areas, while at the same time meet digitalisation trends and increased quality of life. Demographic change, with aging populations, as well as depopulation of remote European areas and regions, combined with urban sprawl are ongoing trends, that were only (in part) slightly reversed by the COVID-19 pandemic. Rental prices in European capitals continue to be on the rise, which is on the one hand related to inflation as a result of several crises, but also due to a lack of supply in main urban regions.[29]

At the same time, the construction industrial ecosystem has an aging workforce, with an estimated 1 million workers needed by 2025. Attractiveness, changing needs, and green and digital skills are among the challenges to overcome to attract the required workers.[30]

[28] Development and implementation of initiatives fostering investment and innovation in construction and demolition waste recycling infrastructure' (2018) https://op.europa.eu/en/publication-detail/-/publication/3637d9db-1c3e-11e8-ac73-01aa75ed71a1/language-en/format-PDF/source-277682930

[29] Housing Anywhere (2022) Housing Anywhere International Rent Index by City Q4 2022 https://housinganywhere.com/rent-index-by-city

[30] European Commission (2021) Scenarios for a transition pathway for a resilient, greener and more digital construction ecosystem.

2. Technological trends

Key findings
Technological shifts in the construction industry are driven by the need for a greener and more digital, future proof industry that responds to current needs. The green transition is tightly linked to the capabilities of the industrial ecosystem **to improve energy and material efficiency and to enhance circularity**. Digitalisation, including technologies such as **building information modelling (BIM)** is an essential element to improve efficiency and circularity in construction and develop a more efficient management of resources and of the built environment. Patent applications in the construction industry are used in general to protect an innovative feature of a new building, structure or component for instance related to alternative construction methodologies or green building. **Patents in green technologies remain more important than patents in digital technologies** in the construction industrial ecosystem, where green technology patents in construction typically number over 400 per year in the EU27 from 2010 to 2020. **Advanced sustainable materials and air and water pollution reduction technologies** are leading with a 25.6% and 17.85% share within the total twin transition patent applications. **Solar photovoltaics and wind technology** related technologies have been patented the most among the renewable energy technologies. **Additive manufacturing as a part of advanced manufacturing technologies and automation** (together with autonomous robots in third place) are leading the digital technologies appearing in patent applications from 2017-2021 related to construction. **Green construction tech startups are active in the field of energy (including energy efficiency, renewable energies, energy-saving),** followed by recycling technologies and other green building solutions. Digital construction tech startups are active in the provision of software solutions (46%), advanced digital technologies (41%) and advanced manufacturing (13%). **BIM remains an important construction specific technology**, relying on the interplay with other software-based solutions. Robotics in construction is growing in importance, with interesting applications to address labour shortages.

Technological shifts in the construction industry are driven by the need for a greener and more digital, future proof industry that responds to current needs. However, these are slowed by the overall pace of technological uptake known to the construction industry. The green and digital transitions in the construction industry are underpinned by green and digital technologies either developed by the construction industry itself or applied to construction coming from other industries. Construction technology companies are engaged in providing technological solutions to the industry. This can include a broad range of techniques, software, machinery that aim at enhancing productivity and advance innovation. It can comprise advanced materials, additive manufacturing, robotics, or modular construction.

The **green transition in construction** is driven by the need to reduce the environmental impact of the construction industry by both improving energy and material efficiency and recyclability.[31] This is apparent from the use of green technologies such as energy saving technologies, renewable energies, advanced materials, and recycling technologies.

Digitalisation, with technologies such as building information modelling are an essential element to improve efficiency and circularity in construction and develop a more

[31] European Construction Sector Observatory. 2018. Improving energy and resource efficiency. Analytical Report. https://single-market-economy.ec.europa.eu/document/download/9dc437a6-5edf-498c-a92c-37e5384a643b_en

efficient management of resources and of the built environment, showcasing the interplay of the twin transition. At the same time, digitalisation allows to improve the efficiency of design and planning stages of construction projects in term of human resource required but also project execution. In the area of digital technologies, advanced manufacturing and robotics, artificial intelligence, augmented and virtual reality, big data and cloud computing, blockchain, and internet of things play a key role.

The Methodological Report of the Monitoring industrial ecosystems (EMI) project outlines the core technologies considered as a part of the green and digital transition in this project, with industry specific technologies highlighted for the construction industry.

In the next sections, technological trends and new business models in the construction ecosystem have been captured by a range of different indicators, stemming from different data sources, such as patent and startup data.

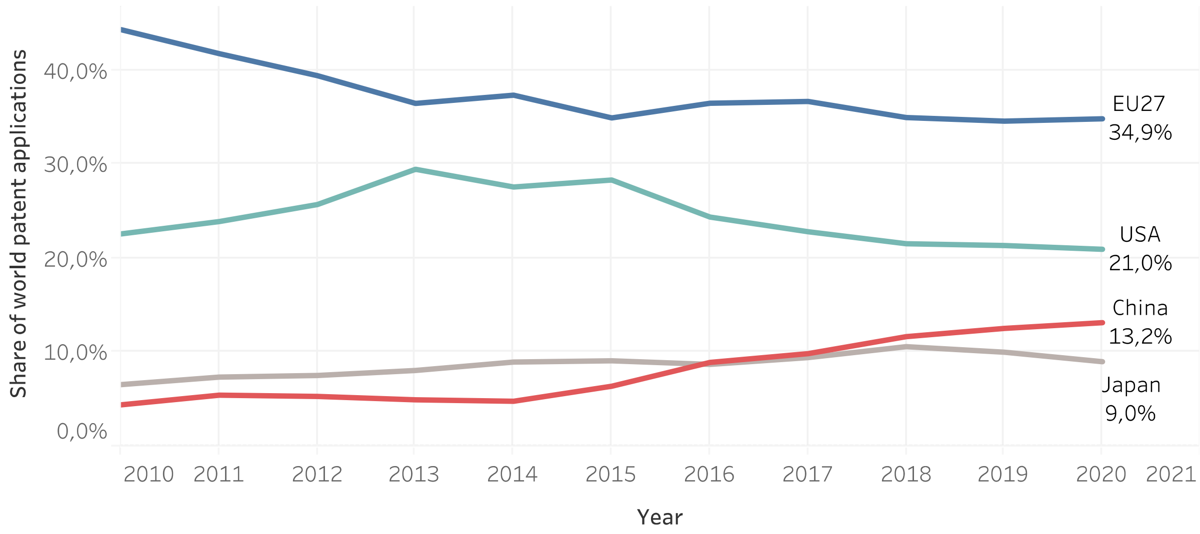
2.1 Emerging technologies

Patent applications in the construction industry are used in general to protect an innovative feature of a new building, structure or component for instance related to alternative construction methodologies or green building.

Technology developments have been tracked by patenting activities related to the specific sectoral activities. The analysis is based on 'transnational patents' (Frietsch/Schmoch, 2010) (i.e. PCT/WIPO filings or direct applications at the EPO, excluding double counts) and was conducted on an extended version of the EPO's Worldwide Patent Statistical Database that Fraunhofer ISI implemented locally. Technologies-relevant-to-ecosystems are defined based on a search that refer to patent classifications (IPC) and/or use keywords to identify relevant applications across classes. The detailed methodology is presented in the EMI methodological report.

Figure 6 highlights the share of patent application filed in the EU27, China, South Korea, Japan and the USA over the period of 2005-2020.

Figure 6: Trends in the share of patent applications in world total in the construction industrial ecosystem in 2005-2020 for EU27, China, USA, Japan, South Korea



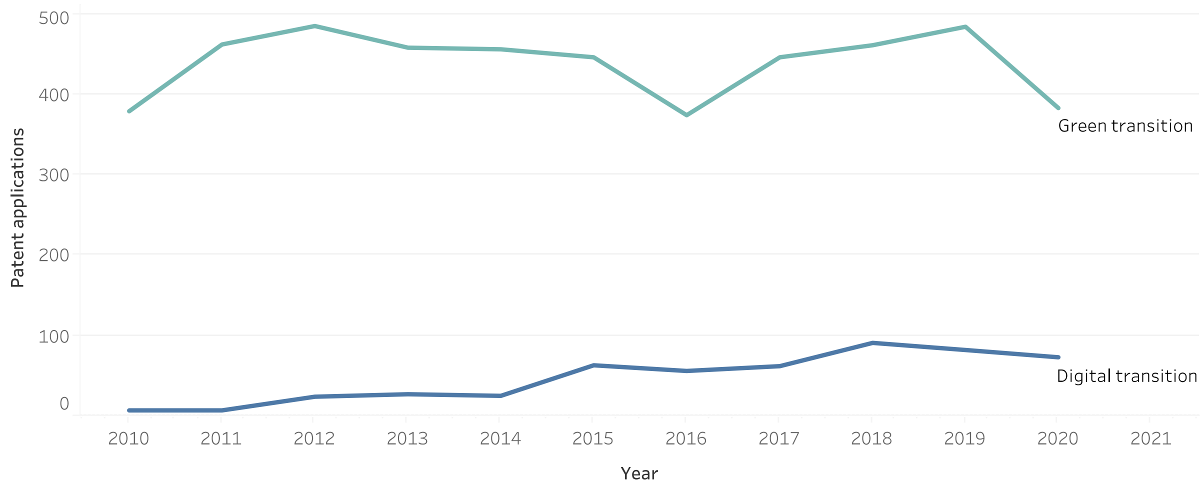
Source: Fraunhofer calculations, Patstat

The EU27 shows a general reduction in patenting over the period of observation, while China and Japan show increasing trends. The US, and South Korea remain relatively constant during the period of observation. The decline in the majority of the patenting activities can be attributed to the fact that several key patents, e.g. on digital technologies that are applied to the construction industry are adapted to the industry, but not necessary filed within the industry itself. This trend is likely to reverse itself post-2020 in response to the increasing demand for green technologies to respond to the energy efficiency of buildings developed by the construction industry.

A complementary analysis was carried out to zoom in specifically on the **developments in patenting related to the green and digital transition**. The analysis of digital and green patent applications related to the construction industrial ecosystem was based on the analysis of the 2022 edition of the OECD REGPAT database. Specifically, the analysis built upon the Cooperative Patent Classification (CPC) classification. A text mining algorithm was used to search for keywords and their specific association in the text of patent documents as well as in the Cooperative Patent Classification nomenclature. By using this approach, we can representatively capture the patenting activity the construction industrial ecosystem. It has to be noted that the focus is on the patent application that is related to the construction industry, but this does not mean that the patent application was submitted by a construction firm or organisation. The classification of green and digital technologies underpinning these transition builds on both the OECD green patents classification and work of Balland and Boschma (2021) and includes additional technologies particularly relevant to the construction industrial ecosystem.

Patenting in green technologies remains more important than digital technologies in the construction industrial ecosystem, as depicted in Figure 7. The importance of green technology patenting trends is highlighted by the number of patent applications in these technologies in the construction ecosystem over time. From 2010 to 2020, **green technology patents in construction typically number over 400 per year** in the EU27. Digital technologies remain under 100 per year, though with continually increasing importance. The dip in the year 2020 can be clearly associated with the COVID-19 crisis, which evidently had a greater impact on the green technologies underpinning the green transition than the digital technologies underpinning the digital transition. It has to be also kept in mind that there is a time lag in finalising patent applications and the year 2020 might be updated in the following years when more data become available.

Figure 7: Green and digital patenting trends in construction ecosystem over time (2010-2020) in the EU27



Source: Balland, 2022 based on PATSTAT

Overall, **the patents for the construction industrial ecosystem lie clearly in technologies supporting the green transition**. The higher share of green technologies in the construction industrial ecosystem patents points towards the increasing need to address the environmental impact of the construction industrial ecosystem, which is also motivated by the European Green Deal and the objective to build and renovate in an energy and resource efficient way. Results highlight that advanced sustainable materials and air and water pollution reduction technologies are leading with a 25.7% and 17.9% share within the total twin transition patent applications. The use of renewable energy also plays a key role towards the transition to zero energy buildings. Solar photovoltaics and wind technology related technologies have been patented the most among the renewable energy technologies.

Figure 8: Most relevant green and digital technologies, EU27 in global comparison with USA and China (2017-2021)

Technologies	EU27		USA	China
Green transition				
Advanced Sustainable Materials	25,7%			
Air & Water pollution reduction	17,9%			
Wind energy	12,5%			
Water related adaptation technolc	9,5%			
Solar energy	5,8%			
Recycling technologies	4,1%			
Batteries	3,5%			
Biofuels	2,7%			
Marine & hydro energy	2,1%			
Waste management	1,9%			
Biotechnology	1,4%			
Other energy storage	0,4%			
Hydrogen	0,4%			
Digital transition				
Advanced manufacturing	3,4%			
Internet of things	2,9%			
Autonomous robots	1,3%			
Augmented reality	1,3%			
Artificial intelligence	1,0%			
Cybersecurity	0,9%			
Blockchain	0,6%			
Cloud computing	0,5%			

Legend			
	Low share		High share

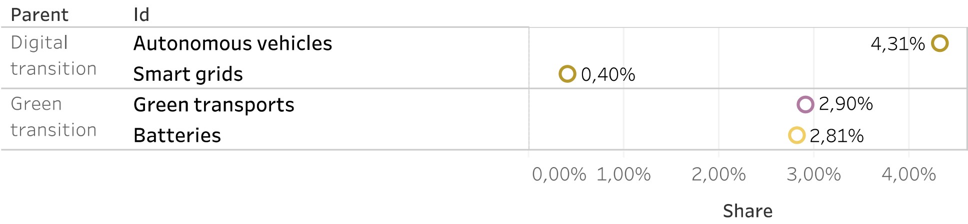
Source: Balland, 2022 based on PATSTAT

Results on the **digital technologies appearing in patent applications from 2017-2021 related to construction** (as presented in Figure 8) show that additive manufacturing as a part of advanced manufacturing technologies (together with autonomous robots in third place) are leading. Internet of Things is also an important and all-encompassing technology related to the underlying digitalisation of industries, especially traditionally low-tech industries such as construction and thus it is not surprising to see this as the second most important digital technology in this patent analysis.

In an international comparison with the USA and China, it can be observed that **while the EU27 is leading in many of the green technological fields, it is behind the USA in the digital transition** except for advanced manufacturing.

Further novel digital and green technological fields are highlighted as a part of the analysis in Figure 9. Notably, autonomous vehicles stand out among the digital technologies as having a high importance especially related to the construction of infrastructure projects related to 5G and the necessary supporting infrastructure to enable autonomous vehicles and their use in Europe. Likewise, transport is an important underlying theme for the green transition related technological developments in green transports and batteries related technologies, which also show high relevance for patenting in the construction industrial ecosystem.

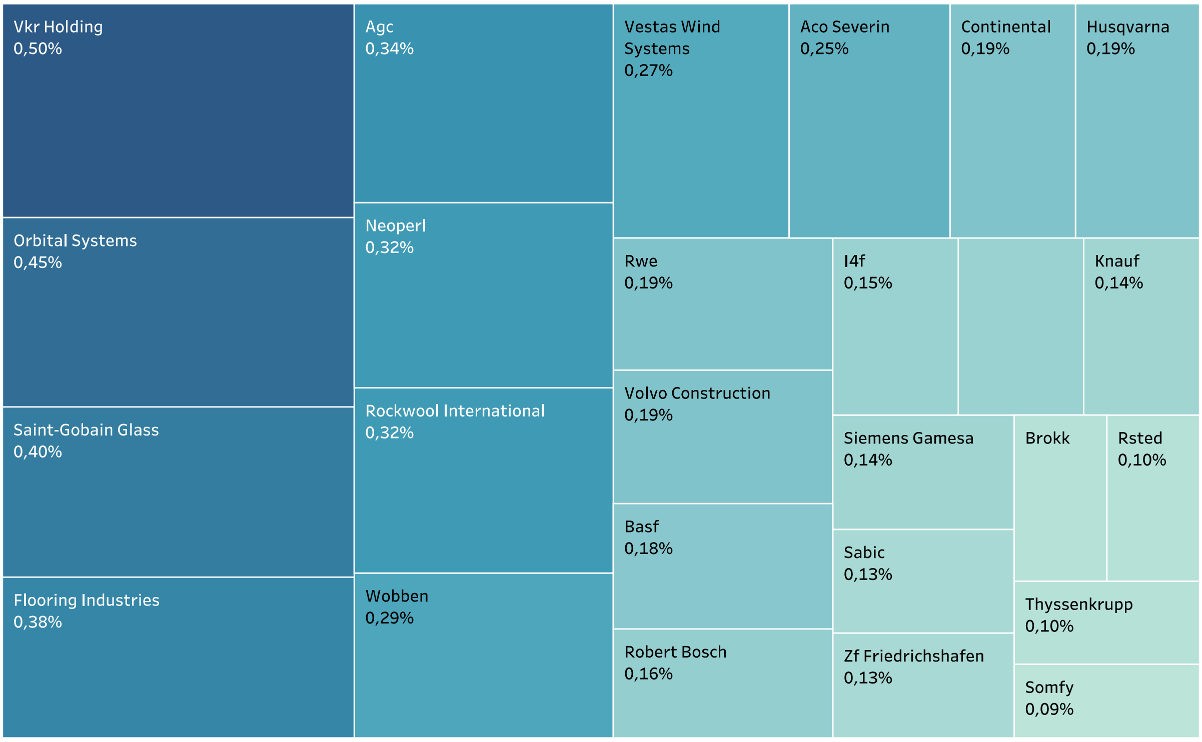
Figure 9: Patenting in other novel digital and green technological fields in the EU27



Source: Balland, 2022 based on PATSTAT

Zooming in, we also examine the applicants behind these patenting activities. Figure 10 presents the top 25 applicants behind the green and digital transition related patenting activities in the examined data set. Notably Vkr Holding (DK), Orbital Systems (SE), and Saint-Gobain Glass (FR) stand out among the top 3. **Energy and resource efficiency is a clear theme amongst these companies**. Vkr Holding notably focuses on roof windows and skylights as well as vertical windows and doors, with an emphasis on energy efficiency.[32] Orbital systems focuses on smart water solutions especially for taps and showers.[33] Saint-Gobain Glass develops high performance glass for green houses, homes and living spaces as well as industrial applications.[34]

Figure 10: Top 25 applicants with the highest share of green and digital construction related patent applications in the EU27 (2017-2020)



Source: Balland, 2022 based on PATSTAT

32 https://vkr-holding.com/
33 https://orbital-systems.com/
34 https://www.saint-gobain-glass.com/hub/products-applications

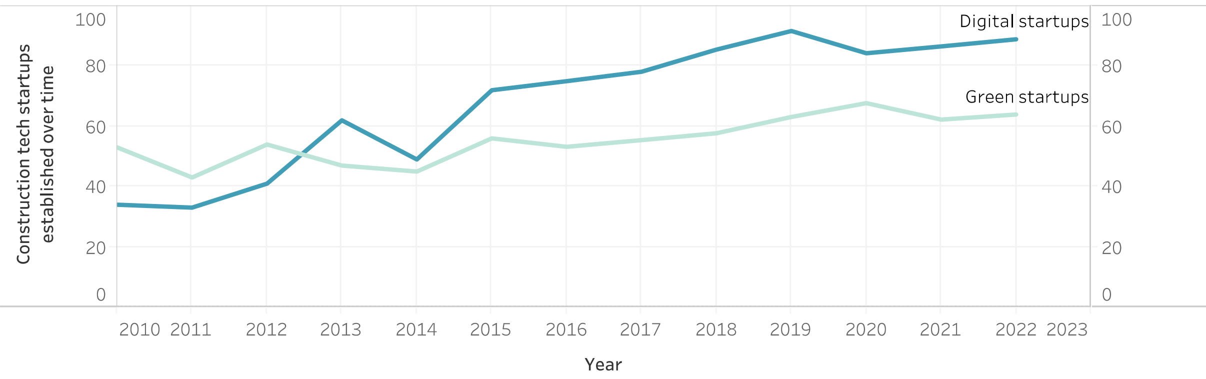
2.2 Twin transition driven by construction tech startups

On the landscape of innovative startups, more and more emphasis has been put on the construction industry and technologies for the green and digital transition. Green technology startups are key actors in the transition towards a green economic model. Entrepreneurial activity helps to accelerate the diffusion of technologies in industrial ecosystems, and startups providing green solutions are good indicators on how the industrial ecosystem is transforming itself to reach environmental sustainability objectives.

An analysis of innovative startups in the green transition (through Net Zero Insights[35]) and digital transition active in the construction industrial ecosystem (through Crunchbase) was carried out. The construction industrial ecosystem was delineated in these datasets in alignment with the tagging scheme available through the dataset, where the specific tags used are indicated in the methodological appendix.

Based on this analysis, Figure 11 presents the **evolution of the innovative construction tech startups active in the green and digital transition since 2010**. The trends indicate a growing importance of digital technologies as compared to green technologies, though both experience positive trends. From the analysis it is evident that COVID-19 impacted the digital technology startups negatively, and the green technology startups positively in 2020 and inversely in 2021, with green startups decreasing and digital recovering.

Figure 11 Evolution of construction tech companies per year of founding (2010 onwards, N=1602) in the EU27



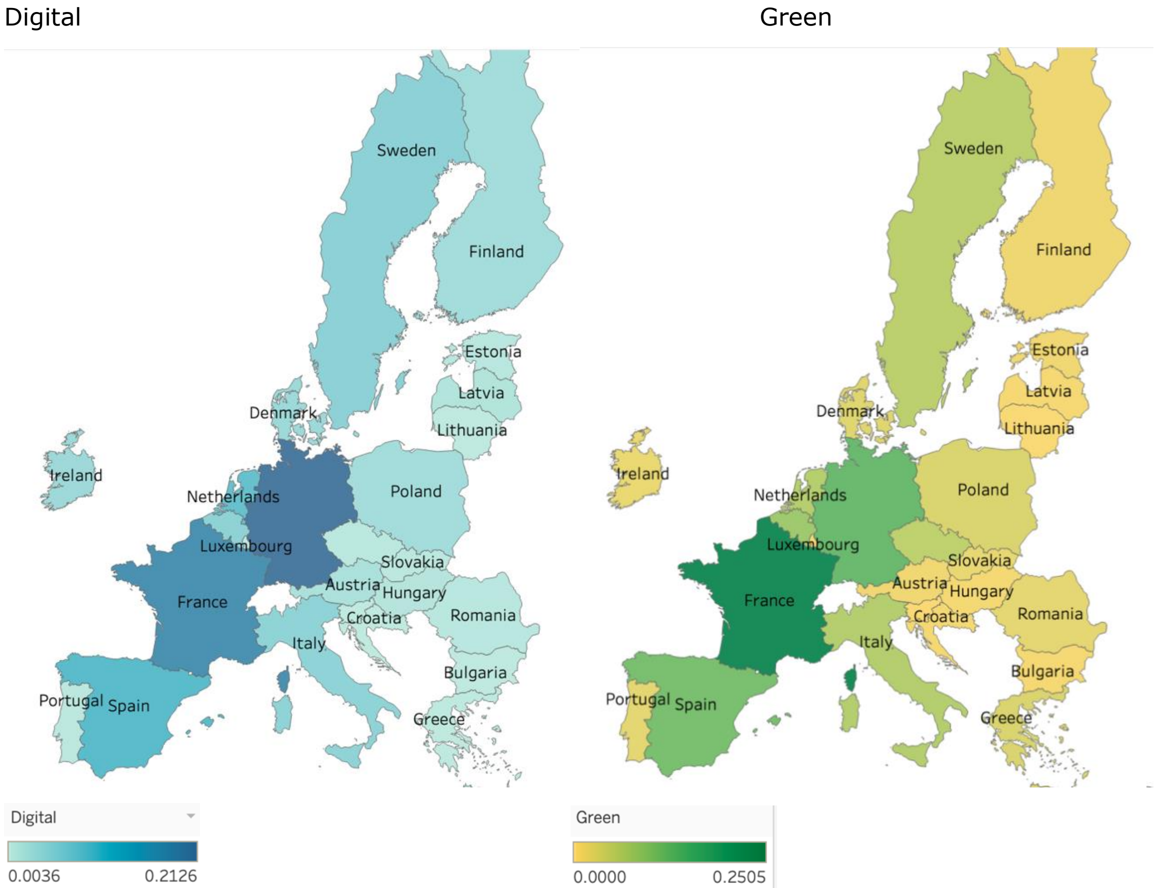
Source: Technopolis Group based on Crunchbase and Net Zero Insights data, 2022

In terms of country trends in innovative green and digital construction tech startups Figure 12 presents the EU-27 countries with the highest number of tech startups. In both instances, Germany, France, and Spain stand out.

Zooming in on the technological focus of the **green construction tech startups**, the data presented in Figure 13 indicates that the highest share of companies are active in the field of energy (including energy efficiency, renewable energies, energy-saving), followed by recycling technologies and other green building solutions. Digital technologies for environmental sustainability (analytical software, including BIM, 3D, AI, IoT and blockchain) are also prominent in addressing the green challenge, which points towards the general notion of the twin transition, where both technologies go hand in hand. An example of such a construction tech company active in the green transition with digital technologies is presented in Box 1.

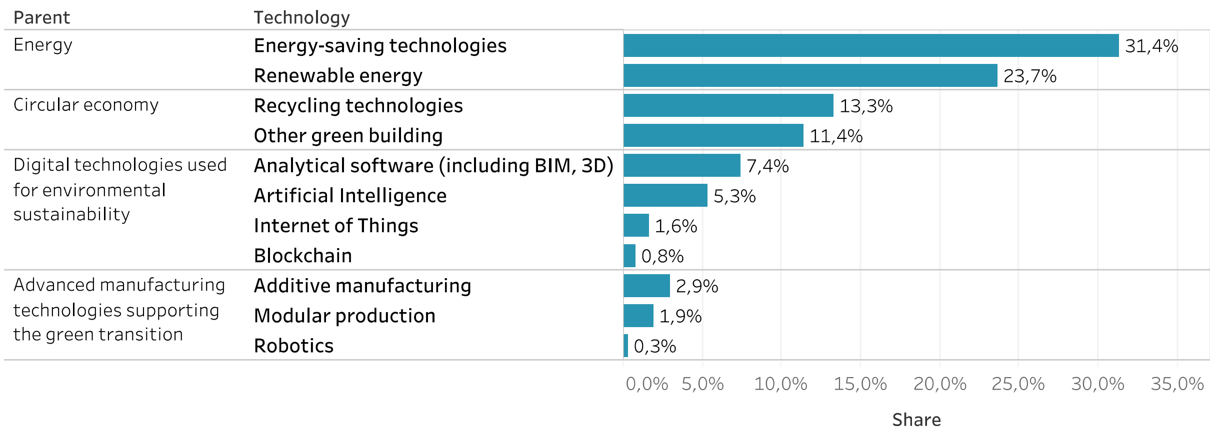
[35] NetZero Insights is a database specialised in capturing sustainability driven startups and therefore covers widely the innovations that are being developed in the context of the green transition.

Figure 12: EU27 countries with the highest share of digital and green construction tech startups (established after 2010)



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

Figure 13: Type of green technologies and solutions provided by construction tech startups (established since 2010)



Source: Technopolis Group based on Net Zero Insights, 2022, N=602

Energy, amongst which **energy saving technologies and renewable energy** are the most dominant focal areas in the green transition for the construction tech startups. The focal areas therein include the development of solutions for homes in residential settings but also for businesses. Some solutions for energy saving also focus on window technologies for harvesting energy such as those developed by Next Energy

Technologies[36]. There is also a strong interplay between energy saving technologies and the integration of renewable technologies in homes. Other companies zoom in on renewable energy technologies, for example Eranovum[37], is a Spanish company that manages the development and construction of renewable energy projects in Spain using new era energy infrastructure and boast the delivery of the full life cycle of sustainable energy projects.

Box 1: Green startup active in digital technologies

Founded in 2018, Alcemy enables a completely new type of **cement and concrete** production. Less expensive, with less CO_2 and consistently high quality.

With Alcemy's AI software, production quality can be controlled predictively. This increases the uniformity of cement and concrete, simplifies work in the laboratory and control room, and reduces production costs. This sets the course for a progressive reduction in the CO_2 footprint and significantly simplifies the handling of even the most complex mixtures.

Basically, the same technology is behind their products for cement and concrete production; they use **machine learning** for predictive quality control in cement and ready-mixed concrete plants.

https://alcemy.tech/en/

Source: compiled by IDEA Consult

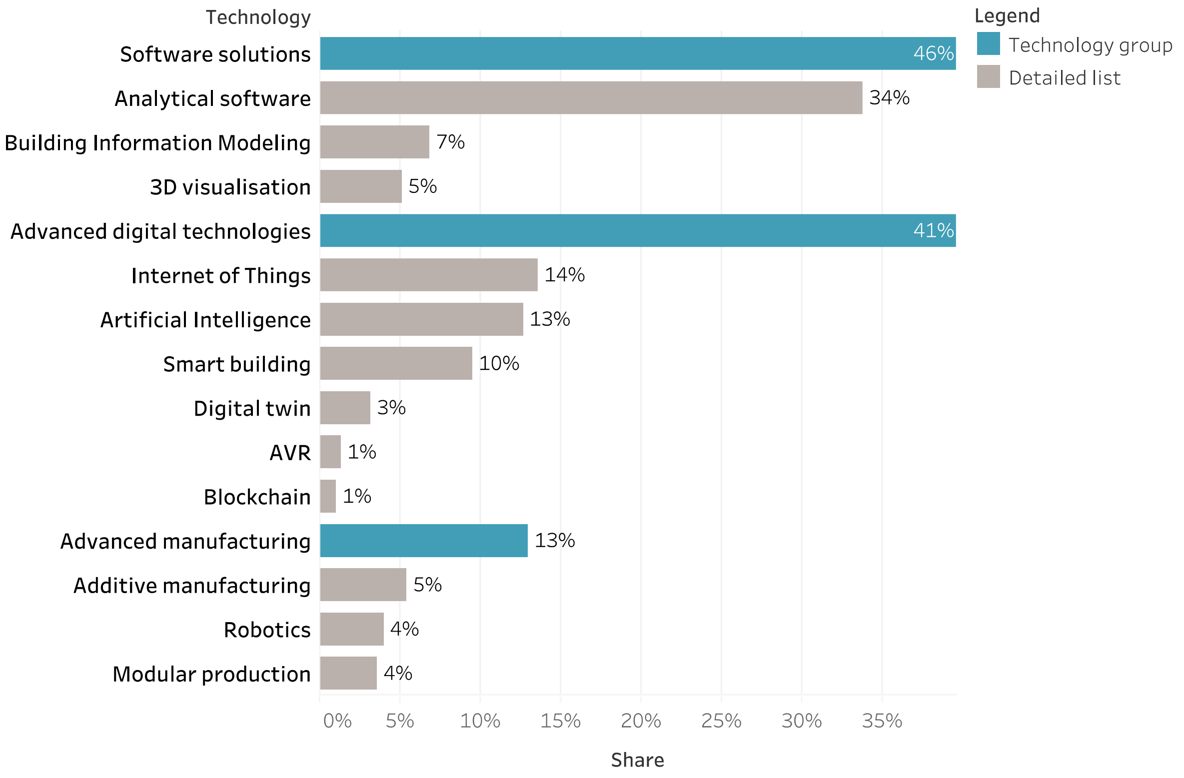
In the area of digital transition, the **digital construction tech startups** are active in three main technological areas as presented in Figure 14, namely in the provision of software solutions, advanced digital technologies and advanced manufacturing. Software solutions are leading the way, with analytical software, Building Information Modelling, and 3D visualisation as a part of the overall group. Within the advanced digital technologies, Internet of Things (IoT) and Artificial Intelligence (AI) are particularly important. Advanced manufacturing consists of additive manufacturing (3D printing) as well as robotics and modular production. The latter, while making up the smallest fraction, presents several technological solutions that actively address specific challenges faced by the construction industry such as the labour shortage as well as the housing crises through modular production.

Within the **software solutions** category, **Building Information Modelling** presents a particularly important technological solution for the construction industrial ecosystem. Pointscene (Finland)[38] stands out as a startup that develops a cloud-based solution for digital processes in construction projects bringing together BIM and 3D visualisation technologies. Datasets can be integrated such as those arising from reality captures, drone mapping, laser scanning and other sensor-based information into the BIM. Pointscene provides intelligent but simple tools for site managers and employees to interact with relevant data for everyday site and work planning, progress monitoring and in communication with other stakeholders. In the area of **advanced manufacturing** and **robotics**, KEWAZO[39] is among those companies that are advancing robotics solutions for the construction industry. Specifically, KEWAZO contributes to the digitisation of the use of robotics and the data analytics underpinning their use in the construction industry. Their LIFTBOT uses robotics in scaffolding applications, reducing labour costs by 44%, which not only improves the safety of lifting and hoisting related to scaffolding but also contributes

[36] See http://www.nextenergytech.com
[37] See https://eranovum.energy/en/home/
[38] See https://pointscene.com/
[39] See http://www.kewazo.com

to the labour shortage. This is complemented by further activities in data and analytics to understand and improve construction site and project management.

Figure 14: Type of technologies of digital construction technology startups (established after 2010) and examples



Source: Technopolis Group based on Crunchbase, 2022

3. Technology adoption

Key findings

Technology adoption represents the usability of technologies for companies in their operations towards their dedicated industrial ecosystem and thus represents an important element of the transition of the overall ecosystem.

The results of a large-scale business survey that collected information about the progress towards the green and digital transition in this project show that **38% of respondents had increased their investments dedicated to the green transition and environmental sustainability during the past five years**. The responses also indicate that 47% invested less than 15%, which is a low result. SMEs in the construction industrial ecosystem switched to the use of **energy saving technologies with a share of 23%** adopting this green solution. This finding is not a surprise since energy saving has become very important since the start of soaring energy prices in 2021. While **recycled materials** are the second solution adopted by SMEs, at 22%, 77% of the respondents declare that they use or plan to use less than 20% of recycled materials. Further solutions adopted include recycling technology and solutions as well as renewable energies both indicated by 20% of the respondents. **Construction companies obtained less and less ISO environmental certificates over time**, with low points in 2017 and 2020, and a slight rise towards 2021.

At the same time, **46% of respondents increased their investments dedicated to digital technologies during the past five years**, with 30% of investing less than 5% of their revenue in digital technologies. More specifically:

- 26.6% adopted cloud software and cloud computing
- 13% adopted big data and related data analytics and 9.9% Artificial Intelligence
- 12.6% adopted Internet of Things
- 12.2% building information modelling
- 10.9% augmented and virtual reality
- 4.9% robotics.

3.1 Construction SMEs' uptake of digital and green technologies

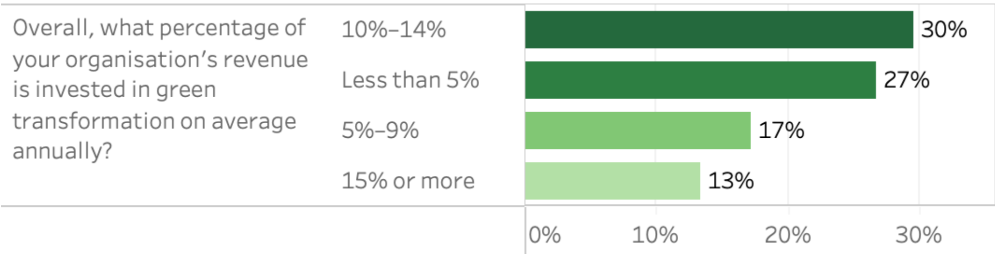
With the objective to monitor the status in the uptake of digital and green technologies, a business survey has been implemented in the framework of this study. The survey collected data about the progress towards the green and digital transition of European SMEs across industrial ecosystems such as construction and gather information about the related investments, challenges, opportunities and expected future developments. The survey was based on using Computer Assisted Telephone Interviewing (CATI). The final sample included 8 987 companies in all industrial ecosystems and **1 003 interviews for construction in particular.** The mainstage fieldwork was conducted between 15 January and 30 April 2023. A prerequisite for each reach-out and interview was to have a respondent with adequate capacities and knowledge to answer the questionnaire (for more details please see the methodological report of the project).

The results of other existing surveys have been also taken into account such as the Flash Eurobarometer 498 on SMEs, green markets and resource efficiency, and the ICT-usage in enterprises survey[40]. The different time of the field work for each survey can give some insights about progress even if the questions were not exactly the same. The Flash Eurobarometer 498's field work took place in November-December 2021. The last ICT usage survey results date from 2020.

3.1.1 Green transformation

When asking construction SMEs, whether they had increased their investments dedicated to the green transition and environmental sustainability during the past five years, 38.1% of the SMEs responded positively. A further question was related to the percentage in terms of revenue that the construction SMEs had invested in green transformation on average annually. The responses show that 47% **invested less than 15%**. The Flash Eurobarometer in 2021 found that **23% of the SMEs surveyed in construction had a concrete strategy in place to reduce their carbon footprint and become climate neutral** or negative, and 18% was planning to prepare one.

Figure 15: Share of revenue invested in green transformation by SMEs in the construction industrial ecosystem on average annually



Source: Technopolis Group and Kapa Research, 2023

The detailed results demonstrate that SMEs in the construction industrial ecosystem switched to the use of **energy saving technologies** with a share of 23% adopting this green solution. Moreover, the Flash Eurobarometer found that a larger share notably 50% of SMEs implemented (including other non-technological) measures to save energy. This finding is not a surprise since energy saving has become very important since the start of soaring energy prices in 2021.

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

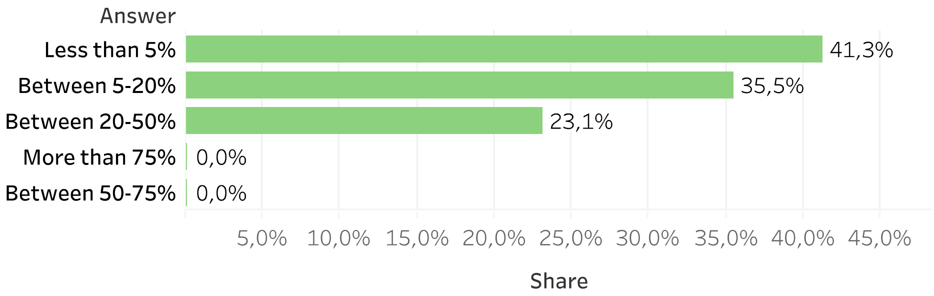
Figure 16: Adoption of green technologies within the construction industrial ecosystem

Green Technology	Already using	Plan to start using in the next 12 months
Energy saving technologies	23%	3%
Recycled materials	22%	1%
Recycling technologies	20%	2%
Renewable energies	20%	2%
Clean production technologies	15%	1%
Advanced sustainable materials	10%	1%
Carbon capture technologies	8%	1%
Hydrogen	3%	1%

Source: Technopolis Group and Kapa Research, 2023

The use of recycled materials was indicated by 22% of the SMEs participating in the EMI survey and **20% also invested in recycling technologies within their own operation.** Again, other non-technological actions have been implemented by a larger share notably 42% as found by the Flash Eurobarometer. Moreover, other types of **advanced sustainable materials** have been adopted by 10% of SMEs in the sample. A further question shows that the share of recycled materials which is effectively used is low. As shown in the Figure below, 77% of the respondents SMEs declared to use less than 20% of recycled materials within construction.

Figure 17: Share of recycled material that is used by respondents within construction projects

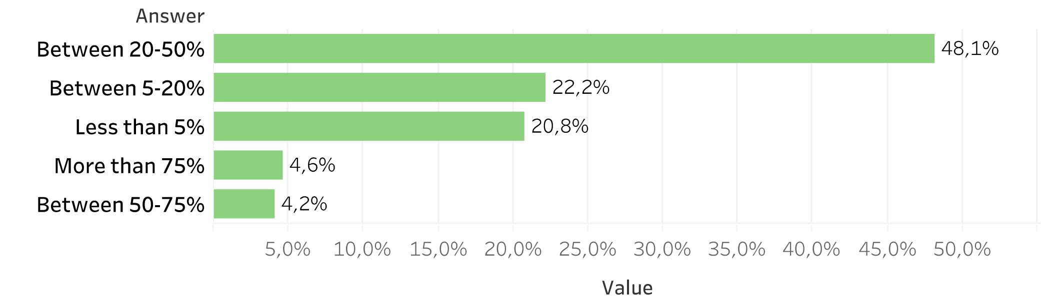


Source: Technopolis Group and Kapa Research, 2023

The least cited technologies include hydrogen, declared by 3% of the SMEs in the sample. In addition, the share of those respondents that have not yet adopted these technologies but planning to do so is relatively low, reaching at maximum 2% of the respondents SMEs.

Renewable energies have been taken up by 20% of the respondents. The results also indicate that 48% of the respondents cover between 20-50% of their total consumption with renewable energy.

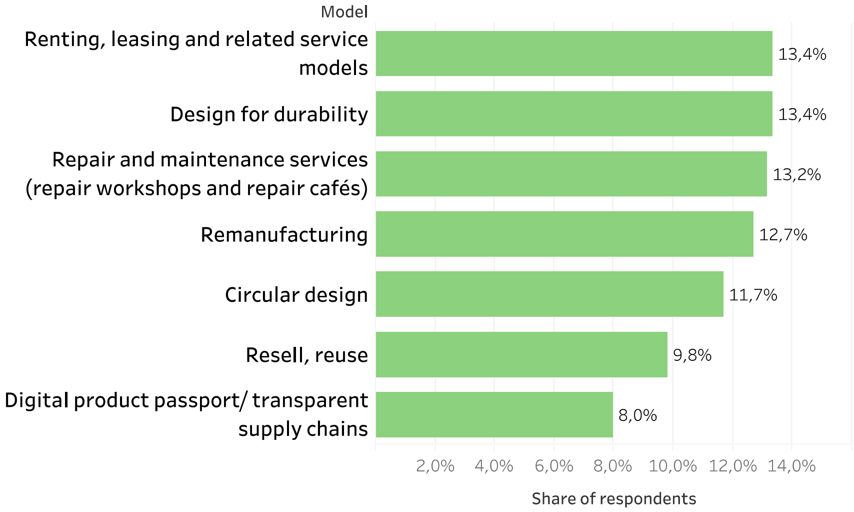
Figure 18: Share of renewable energy use within total energy consumption



Source: Technopolis Group and Kapa Research, 2023

Construction SMEs were surveyed about the **adoption of circular business models** and other environment-focused service models. The results indicate that first 13.4% of SMEs adopted renting and leasing, and the same number also pointed out design for durability. 13.2% of the respondents adopted repair and maintenance services.

Figure 19: Adoption of green business models and non-technological solutions within the construction ecosystem

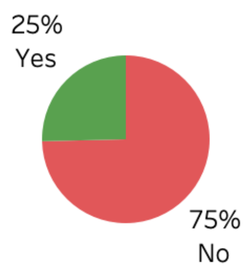


Source: Technopolis Group and Kapa Research, 2023

Environmental standards

When asked about the certification on any environmental standards, 25% of the respondents indicated that they had been certified (see Figure 20).

Figure 20: Share of respondents indicating that they have obtained an environmental certificate from a third-party survey provider

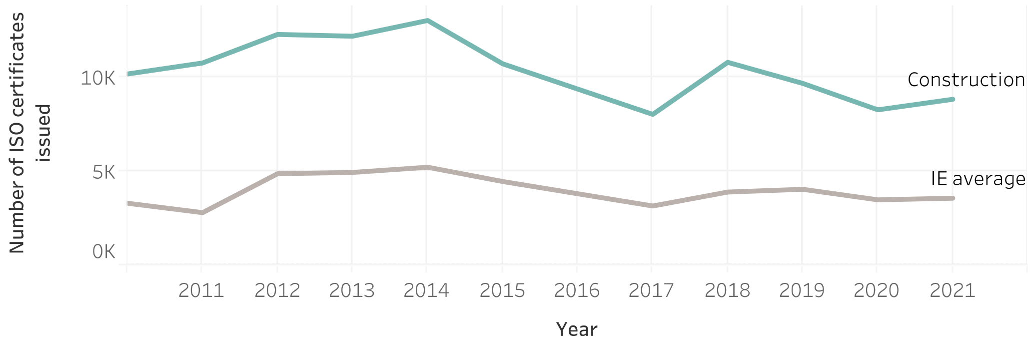


Source: Technopolis Group and Kapa Research, 2023

In terms of **environmental standards,** ISO 14001 is a set of standards that any company can follow to implement an effective environmental management system. By adopting the good practices suggested by the standard, firms can substantially reduce their environmental footprint. The number of environmental certificates issued in the industry indicates the progress towards the application of environmentally friendly business practices and production methods. For the purposes of this report, ISO data were accessed via the ISO survey of certifications to management system standards[41]. The analysis of the data shows that construction companies obtained less and less ISO environmental certificates over time, with low points in 2017 and 2020, and slight rise towards 2021. **The annual ISO survey indicates that there were 10 163 certificates issued to construction industrial ecosystem companies in the EU27 in the year 2010, which number decreased to 8 816 certificates issued in 2021.**

In the construction industry, further certification schemes are in place such as the Energy Performance of Buildings which builds upon the same named directive.[42] The directive was revised in 2018 and a further revision is currently underway, initially presented as a part of the Fit for 55 package in 2021.43 Specifically, Energy Performance Certificates are required as a part of sale or rent advertisements in commercial media, and present suggestions for further renovations in order to increase the overall scoring.[44] Further certification schemes can be considered for their role based on voluntary assessments, especially for those looking to sustainability issues overall, beyond energy performance alone.[45]

Figure 21: Number of ISO 14001 environmental certificates issued in the EU27



Source: Technopolis Group, 2022, based on ISO

3.1.2 Digital transformation

When asking construction SMEs, whether they had **increased their investments dedicated to digital technologies** during the past five years, 46% responded positively. A further question was related to the percentage in terms of revenue that construction SMEs had invested in digital transformation on average annually. The responses show that **30% of the respondents invested less than 5% in revenue** in digital technologies and altogether 78% invested less than 15%.

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

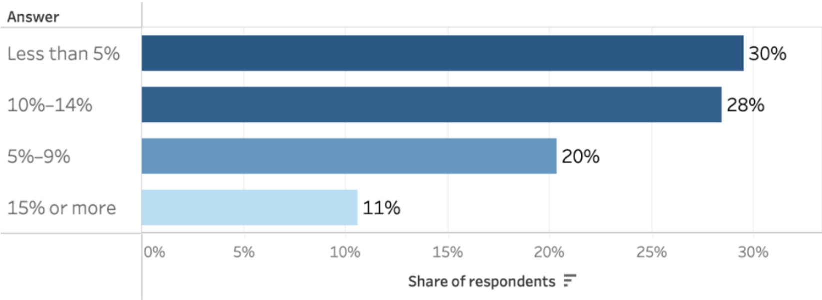
[42] https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/energy-performance-buildings-directive_en

[43] https://www.europarl.europa.eu/legislative-train/theme-a-european-green-deal/file-revision-of-the-energy-performance-of-buildings-directive

[44] https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/certificates-and-inspections_en

[45] https://energy.ec.europa.eu/system/files/2014-12/Final%2520report%2520-%2520Building%2520Certification%2520Schemes%2520-%2520FINAL%252026112014_0.pdf

Figure 22: Share of revenue is invested in digital transformation on average annually



Source: Technopolis Group and Kapa Research, 2023

The adoption of specific digital technologies is shown in the Figure below. The detailed results demonstrate that besides the popularity of **cloud software and cloud computing (used by 26.6%), construction SMEs adopted online platforms and big data (21%).** Moreover, **Internet of Things and building information modelling are in use by 12% of the respondent SMEs.** It has to be noted that the shares have to be interpreted in light of the relevance of each digital technology for the sub-industries of the ecosystem. Building information modelling (BIM) is a process that allows the creation of a digital representation of a physical asset via 3D modelling and has been found to be adopted more in architecture than in building construction directly.

Figure 23: Adoption of digital technologies within the construction industrial ecosystem

	Answer	
Technologies	Already using	Plan to start using
Cloud computing	26,6%	0,8%
Online platform	24,1%	2,2%
Big Data	13,8%	3,6%
Internet of Things	12,6%	2,9%
Building information modelling	12,2%	1,6%
Augmented and virtual reality	10,9%	3,9%
Artificial intelligence	9,9%	4,3%
Digital twin	8,2%	2,7%
Telematics solutions	6,3%	1,8%
Robotics	4,9%	3,5%
Blockchain	3,9%	2,6%

Source: Technopolis Group and Kapa Research, 2023

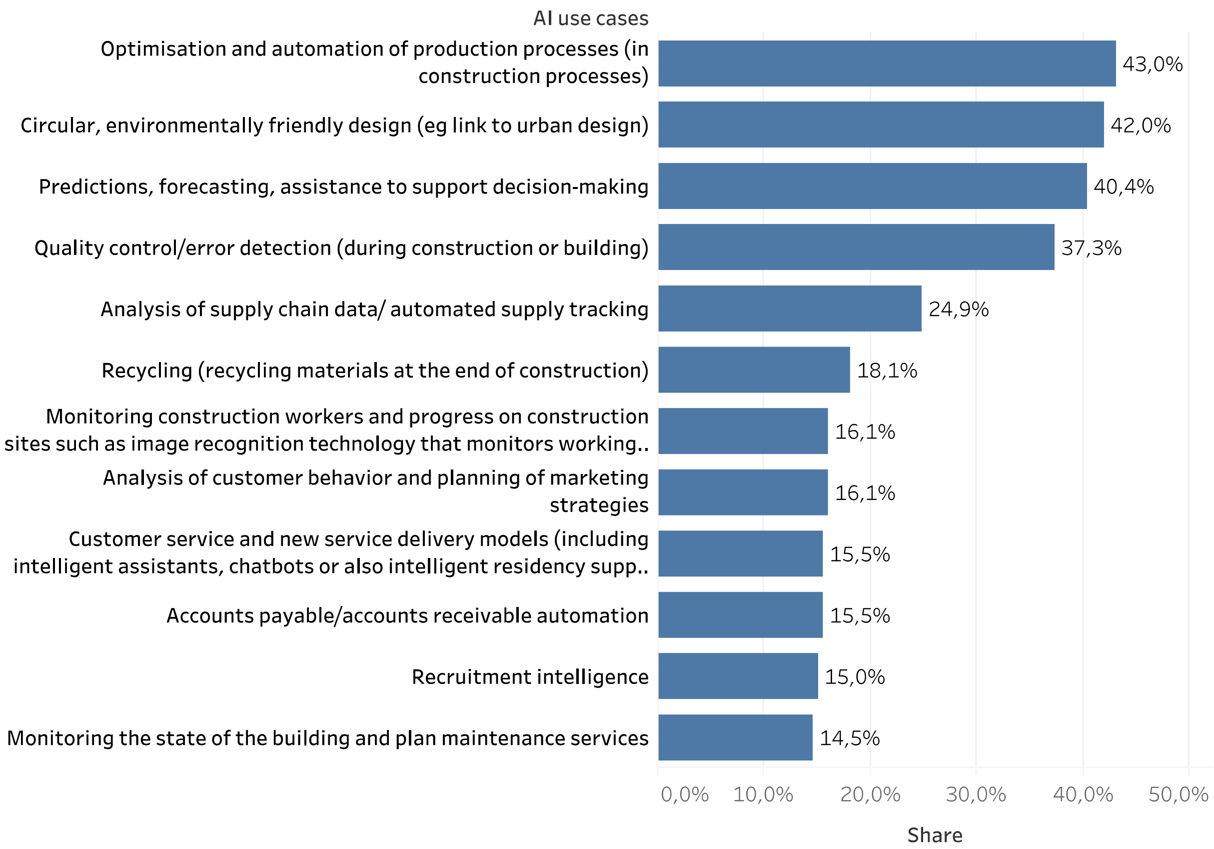
Artificial Intelligence

Artificial Intelligence has been adopted by 9.9% of the respondents in the construction ecosystem. The related indicator in Eurostat[46] that measures the use of AI by enterprises by economic activity found that 4.8% of enterprises in construction (10 persons or more) adopted at least one Artificial Intelligence technologies in 2021. However, this category does not include the full ecosystem and other important activities such as architecture and services to buildings.

[46] https://ec.europa.eu/eurostat/databrowser/view/ISOC_EB_AIN2__custom_7239921/default/table?lang=en

Additional questions revealed the areas where Artificial Intelligence have been focused on along the construction industrial value chain. Respondents that have specified these technologies include optimisation of production processes, circular and environmentally friendly design, and predictions to support construction and building materials. Moreover, AI technologies have been adopted with the objective of automatising production processes, implementing quality controls and obtaining 'smart construction materials'.

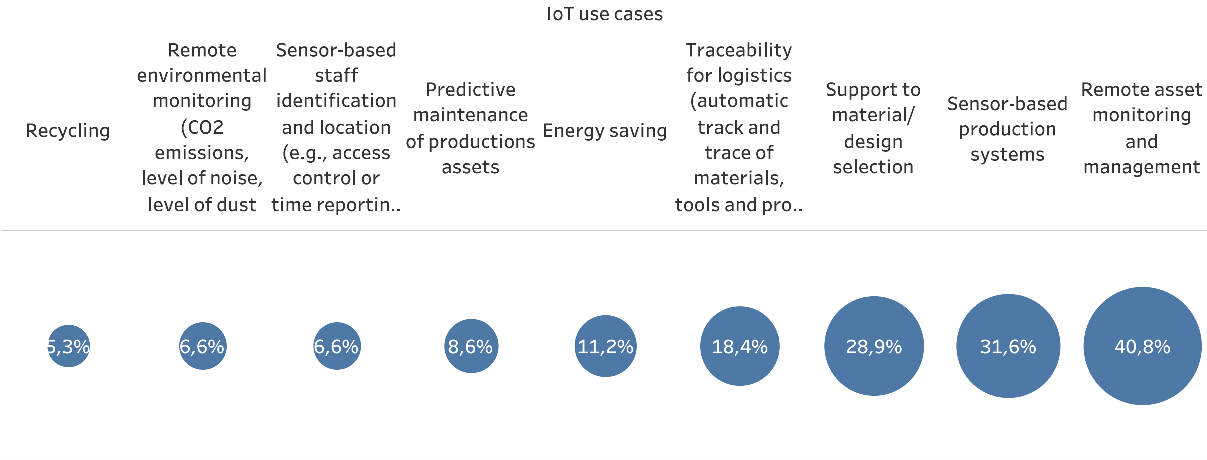
Figure 24: Use cases of AI and big data of construction SMEs



Source: Technopolis Group and Kapa Research, 2023

Internet of Things is used by 13% of the respondents. IoT is often used for remote asset monitoring and management, in sensor-based production systems, but also to support design. For instance, IoT was pointed out to help the optimisation of performance and efficiency during architectural design as it allows gathering useful data from sensors and related devices.

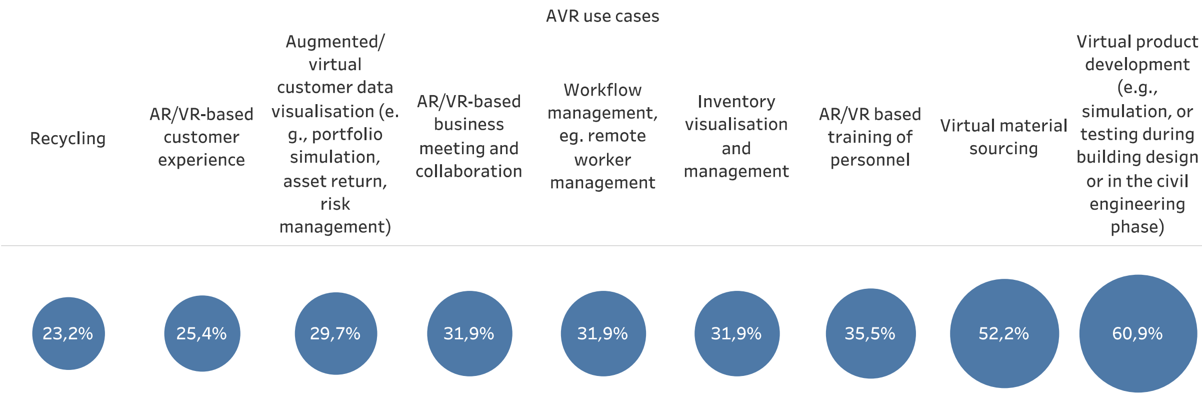
Figure 25: Use cases of Internet of Things of construction SMEs



Source: Technopolis Group and Kapa Research, 2023

Augmented and virtual reality (AVR) was adopted by 10% of the respondents in the survey. AVR can help visualise the design and layout of a building and allows stakeholders to see how it would look like in real. It can also enable virtual tours of the construction project.

Figure 26: Use cases of augmented and virtual reality of construction SMEs



Source: Technopolis Group and Kapa Research, 2023

Robotics had a rate of 4.9% of the respondents in the broader ecosystem investing in these technologies. Eurostat[47] indicates that 3% of the enterprises in construction (10 persons or more) used industrial or service robots in 2022.

Blockchain has been mentioned by a very low number, notably 4% of the respondents. Those very few that responded yet, pointed out the use of blockchain for product and service traceability, quality tests, asset and goods management, payments, and supply chain tracking.

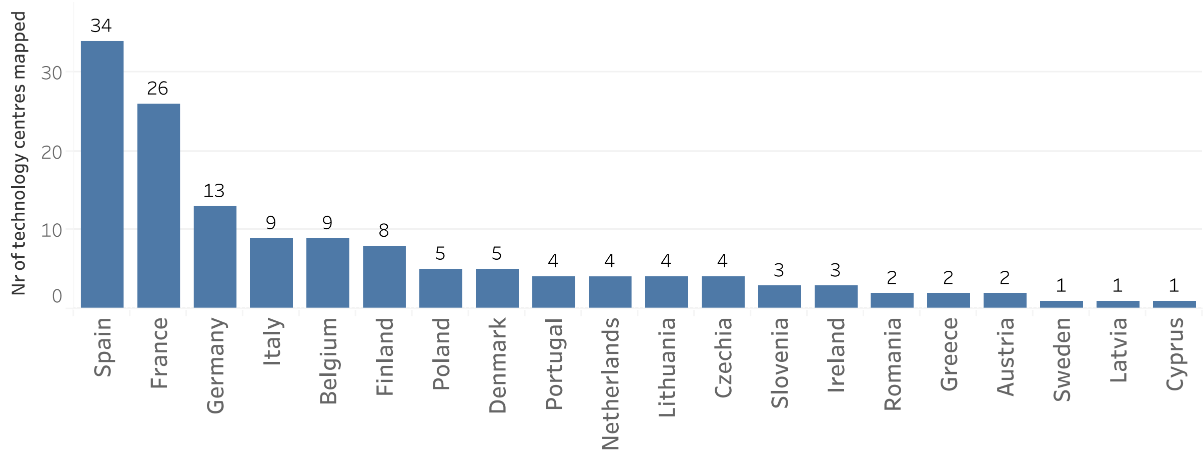
[47] https://ec.europa.eu/eurostat/databrowser/view/ISOC_EB_P3DN2__custom_7153061/default/table?lang=en

3.2 Technology centres fostering access of SMEs to technologies

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

Figure 27 presents the number of technology centres (TCs) that are active in the construction industrial ecosystem per European country and shows that Spain (34) is the country with the higher number of technology centres in Europe, followed by France (26) and Germany (13). The top 5 is further complemented by Belgium (9) and Italy (9). These countries might host additional technology centres active in the construction industrial ecosystem, which are currently not registered to the technology centres mapping.

Figure 27: Technology centres per country – construction



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

The following examples serve to illustrate the activities and scope of technology centres active in construction, their links with the broader ecosystem as well as examples of recent activities in which they are involved. Centre technique de matériaux naturels de construction, CTMNC presents an example of a building materials dedicated technical centre that is particularly contributing the green transition focussing on energy efficiency and decarbonisation of industry as a part of the ALLICE initiative (see Box 2). CertiMaC (IT) presents (see Box 3) an Italian TC that boosts innovation in the building and construction industry through support for R&D, testing and certification. ZAG, as one of three Slovenian TCs, is particularly active in emissions reduction through EU and industrial projects (see Box 4).

Box 2: Example Technology Centre: Centre technique de matériaux naturels de construction, CTMNC (FR)

Name of the Centre	**Centre matériaux naturels de construction, CTMNC (FR)**
Location and scope	
The Technical Centre for Natural Building Materials (CTMNC) has the status of an Industrial Technical Centre (ITC). It promotes innovative techniques and has contributed to improving the quality of building materials for sixty years.	

CTMNC has expertise in the characterisation, manufacturing, and use of fired clay, unfired clay, and natural stone as building materials and in their combination with other building materials.

CTMNC has engineers and technicians spread over three geographical sites (Clamart, Limoges and Paris) and high-performance equipment:

- a laboratory for testing materials, products and works
- a laboratory dedicated to research and development on ceramic behaviour (characterization, processes, and surface covering)

CTMNC belongs to several French (Network of industrial technical centres CTI, Carnot Institute for Materials and Equipment for Sustainable Building MECD, Ceramics Cluster PEC, Industrial Alliance for Competitiveness and Energy Efficiency ALLICE) and European networks (Tiles and Bricks Europe TBE, The European Ceramic Industry Association Cerame-Uni, European Sustainable Industry Association.

Main services and equipment

- **Research and development** to improve the building materials and their manufacturing processes: optimisation of the clay bricks through simulation (thermal, acoustic, mechanical); development of unfired clay bricks; development of functionalized covering; improve the manufacturing processes and the quality of the building materials.
- **Technical expertise on products and buildings:** raw materials characterisation, masonry and roofing testing, product testing (COFRAC NF EN 17025), support and recommendation on building material pathologies, evolution of building systems
- **Support for product and environmental quality certification procedures:** Audit of the NF label, product certification (COFRAC NF EN 45011), life cycle assessment, environmental and health declaration sheets, support on the waste management
- **Support to access the market:** certification, guidelines, BIM.
- **Evaluation of the performance of building materials and building systems** including mechanical behaviour, fire safety, environment, watertightness of roof structure, acoustics, thermal and hygrothermal properties, durability, and ageing.
- Advice and mounting of projects
- Training
- **Technology, normative and regulatory watch:** dissemination of technical, normative, and regulatory information

Recent projects related to the green and digital transition in construction

- **SUPERHERO Project** (LIFE): aims to promote the use of ventilated permeable roofs (VPR) as sustainable and cost-effective "passive cooling" technology able to increase building occupants' and cities summer comfort and decrease buildings' energy and green-house gasses emissions.
- CTMNC joined **ALLICE** in 2020, an alliance dedicated to energy efficiency and the decarbonisation of industry. Its aim is to accelerate innovation and develop new solutions by bringing together various stakeholders, including supply-side &

demand-side players, specifiers, skills and research centres, investors, and financiers.

Source: Advanced Technologies for Industry Technology Centre Mapping, 2023 and CTMNC, 2023 http://www.ctmnc.fr/

Box 3: Example Technology Centre: CertiMaC soc. cons. a r.l. (IT)

Name of the Centre	**CertiMaC soc. cons. a r.l. (IT)**
Location and scope	
CertiMaC is an Italian private no-profit Research Centre and Material Innovation Lab of Emilia-Romagna High Technology Network – Construction and Energy & Environment Platform and within the Technopole of Ravenna, boosting the innovation processes of the building and construction industry through research & development, testing and certification of advanced and innovative materials, products and solutions, particularly on Energy Efficiency, Building Envelope and Durability. It was founded by ENEA (National Agency for New Technologies, Energy and Sustainable Economic Development) and CNR (National Research Council) – the two main Italian Research bodies - to offer innovation and competitiveness support to the building industry. CertiMaC cooperates with national and international networks of Research Centres, Universities and Innovation Centres and it is part of ECTP and the EIT on Raw Materials. It plays an active role at European level, as a member of the European Steering Committee, in the processes of Development and Validation of methodologies for testing freeze/thaw and weathering resistance and it is the only Italian representative within the international round-robin for experimental validation of testing methods.	
Main services and equipment	

• **Materials testing laboratory**: Analysis, tests, and experimental measurements with more than 400 tests in the catalogue (Environmental and durability testing laboratory, Mechanical testing laboratory, Chemical and physical testing laboratory, Thermal testing laboratory).
• **Energy Efficiency**: Energy audits, monitoring of consumption and environmental health. Consulting for industrial energy management. These are the services provided under this area include ISO 50001 consulting, energy retrofitting, energy simulation, environmental monitoring, energy efficiency incentives, energy monitoring and energy audit
• **Specialist consulting**: CertiMaC supports companies and operators in the sector for the realization of industrial research projects, technology transfer initiatives, development of innovative systems and technologies and of advanced materials, product and process optimization and engineering, training, and technical and regulatory updating interventions. These are the specific services provided:
    o Incentives for research and development
    o Product and process technical consultancy	

- Research and development for the ecological transition • **Certification**: They offer a guarantee of compliance with the required standards and support companies to tackle the national, European, and international market. • **European Projects & Funding**: It provides international experience of testing, development, and certification of innovative building materials to formulate joint proposals on energy efficiency of buildings and sustainable innovation in the field of materials science. • **Academy**: Offers webinars and trainings.
Recent projects related to the green and digital transition in construction
• CertiMaC has collaborated in the implementation of an energy efficiency portal[48] which aims to support SMEs and stakeholders on their path to greater energy efficiency and sustainability. The platform has been developed under the framework of the GEAR@SME[49] European project. The project starts from the assumption that the SME sector has enormous potential to reduce energy consumption. So far, however, this potential has only been partially exploited due to a lack of time, capital and specific expertise.

Source: Advanced Technologies for Industry Technology Centre Mapping, 2023 and CertiMaC, 2023 https://certimac.it/

Box 4: Example Technology Centre: Slovenian National Building and Civil Engineering Institute, ZAG (SI)

Name of the Centre	**Slovenian National Building and Civil Engineering Institute, ZAG (SI)**
Location and scope	
ZAG (Slovenian National Building and Civil Engineering Institute) is a non-profit, state-owned organisation hosting more than 80 experts. It is the Slovenian institute in the field of building and civil engineering. Its main activities include fundamental and applied research, development of new methods of testing and measurement, certification, and attestation of conformity of products, training of research and technical staff in particular technical fields, participation in the preparation of technical codes and standards. ZAG works on the following areas of expertise: buildings, bridges, dams, roads, railways, cableway installations, transmission and other towers, tunnels and underground structures, natural disasters, and other kind of emergencies. The institute is a member of several national European institutes working in the fields of buildings and the infrastructure and co-operates with them in numerous joint research projects. The Institute is a member of organisations such as the European Centre of Information – International Certification Engineer, CEN- European Committee for Standardization, ECTP - The European Construction Technology Platform, EGOLF - European Group of Organisations for Fire Testing, Inspection and Certification or EIT Raw Materials - European Institute of Innovation and Technology, ENBRI - European Network of Building Research Institutes, among others.	

[48] See https://certimac.it/en/newsroom/portal-for-energy-efficiency-in-smes
[49] See https://certimac.it/en/projects/gearsme

Main services and equipment

• The ZAG Department of Materials offers research and development and professional technical support in the field of construction materials, as well as materials of other kinds. The department consists of different labs that work with various materials such as: stone, concrete, cements, mortars and ceramics.
• The Department of Building Physics combines:
  ○ The Laboratory for Thermal Performance and Acoustics, which deals with the field of the thermal and acoustic characteristics of materials and structures, the energy efficiency of buildings, and suitable living conditions in buildings, and carries out various research and testing work in accordance with the presently valid European and other national standards.
  ○ The Fire Laboratory and Fire Engineering is concerned with fire resistance tests and reaction to fire tests of various materials, as well as performing fire safety studies and research and development activities in the wider field of fire safety engineering.
  ○ The Department for research of fire-safe sustainable built environment is a result of a successful project application to the Horizon 2020 ERA Chair call, which is a part of the Spreading Excellence and Widening Participation work program. The department strives to create and support a R&D centre focused on Southern and Central Europe in the field of fire-safe sustainable built environments.
• The Department of Structures investigates and testes structures as well as performs expert studies.
• The Department of Geotechnics and Infrastructure where specialists perform inspections, testing and investigation work in all fields of geotechnics and the traffic infrastructure, both in the field and in the laboratory.
• ZAG's Library is a library in the field of building and civil engineering. It provides everyday information and documentary support to all of ZAG's researchers, technical associates, and experts.
• Certification service
• Research projects

Recent projects related to the green and digital transition in construction
• ZAG's researchers have actively participated in the reduction of emissions and effects on the environment in the building sector. Most of this research work has been joined together into EU and industrial projects, and the TIGR Competence Centre. • Within the project HEAT4U, ZAG co-operated in the development of a gas absorption heat pump for use in individual houses. • In the project BRIMEE, possible applications of bio-thermal insulation were investigated. • The demonstration pilot establishment of a new concept for solar heating and cooling, which was performed within the scope of the project Cost-Effective, includes new conceptual-technological possibilities for the transformation of renewable sources of energy (solar energy).

Source: Advanced Technologies for Industry Technology Centre Mapping, 2023 and ZAG, 2023 https://www.zag.si/

4. Investment and funding

Key findings

The construction industry and industrial ecosystem is known to be a **lagging ecosystem in terms of investments in the green and digital transition** due also to challenges in integration.

Renovation spending in terms of final consumption expenditure of households on maintenance and repair of dwellings is **generally positive over the period of 2011 to 2019**, indicative of the fact that households are increasingly undergoing renovations, however the renovation rate in the EU still remains far below what is necessary to maximise energy efficiency.

Companies in the construction ecosystem are investing over €1.8 bn in R&D&I from 2017 to 2021. **Additive and robotic manufacturing, BIM-compatible plug-ins and applications/4D BIM, and digital twins stand out as being of global importance** for the observed regions for the construction industrial ecosystem.

Venture capital and private equity investment data highlight an **increase in overall investment** both in green and digital construction technology, with digital technologies leading the way in 2022.

In the last decade, the greatest amount of funding for green transition start-ups goes to **early development**, notably early VC funding followed by corporate and series A funding. Innovative green construction tech companies in **renewable energy technologies and energy saving technologies** are attracting the highest investments.

Big data, cloud and other software services, as well as online marketplaces and internet of things and smart building dominate investments in innovative digital construction tech companies.

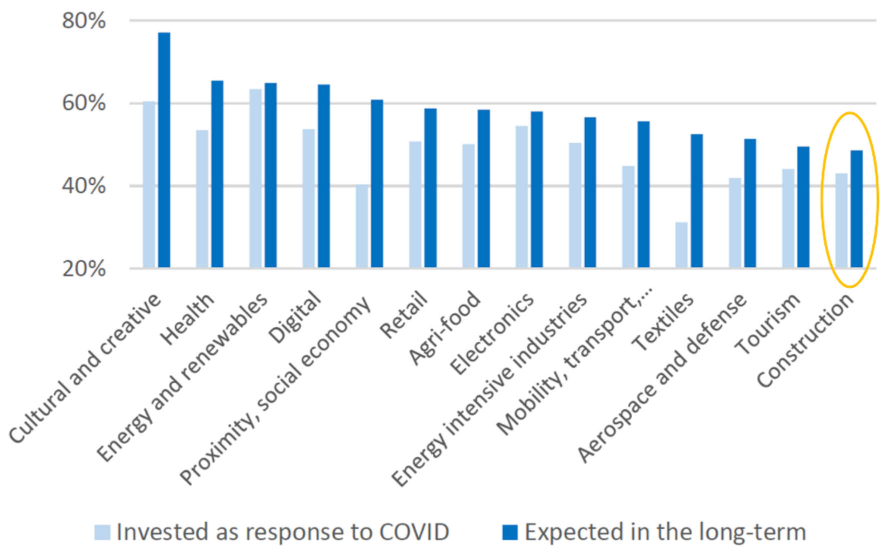
Public procurement on construction was valued at a total of over €825 bn between 2015 and 2020, with over €7.86 bn dedicated to the twin transition (0.95% of the total procurement value (0.82% green, 0.13% digital). **Energy performance, material re-use and the use of photovoltaics made up the most common references underpinning the green transition** in the construction industrial ecosystem.

The Construction industry and industrial ecosystem is known to be a lagging ecosystem in terms of investments in the green and digital transition. The Annual Single Market Report highlights this, especially with regard to the digital transition in Figure 28 and the green transition in Figure 29. In relation to the digital transition, the construction industrial ecosystem is the last ecosystem in terms of investments related to COVID-19 recovery, but also long term expected investment. For the green transition, notably for investments already made to tackle climate change, the construction industrial ecosystem falls in the bottom five ecosystems, however for planned investments in the next three years, the construction ecosystem is in the top five.[50] Investments are further hampered with regard to their potential impact due to challenges in integration of new technology. As for renovation spending, which is important for overall renovation rates underpinning the green transition, the European Construction Sector Observatory maps the renovation spending in terms of final consumption expenditure of households on maintenance and repair of dwellings. The trend depicted in Figure 30 is generally positive over the period of 2011 to 2019, indicative of the fact that households are increasingly carrying out

[50] European Commission 2022 Annual Single Market Report

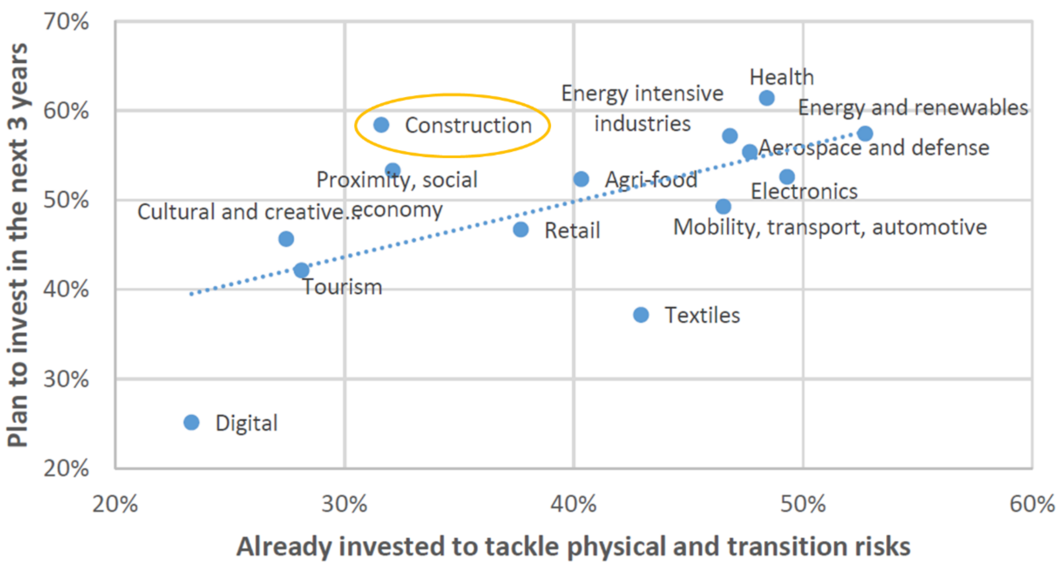
renovations[51], however the renovation rate in Europe still remains far below what is necessary to maximise energy efficiency. That being said, the sector has made strides with passive buildings, net-zero energy buildings and PEBs.

Figure 28: Digital investment and long-term investment expectation (share of firms in %), by industrial ecosystems



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

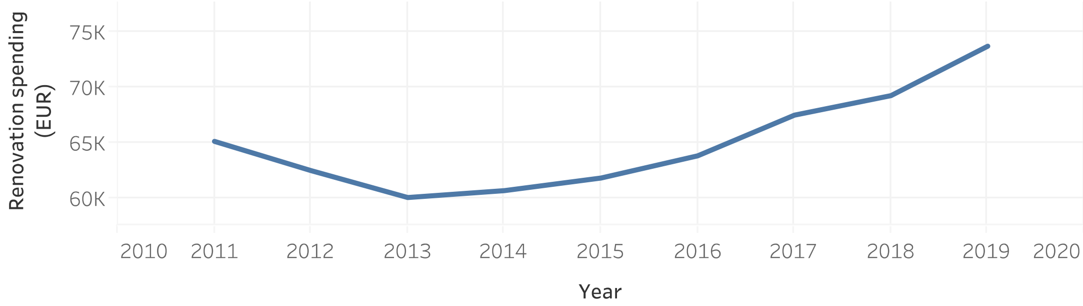
Figure 29: Investment plans to tackle climate change impact, by industrial ecosystem



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

[51] European Commission (2023) European Construction Sector Observatory (ECSO) Data mapper https://single-market-economy.ec.europa.eu/sectors/construction/observatory/data-mapper_en

Figure 30: Renovation spending in the EU27: Final consumption expenditure of households on maintenance and repair of dwellings



Source: European Commission, 2023, European Construction Sector Observatory (ECSO) Data mapper[52]

In this report, we complement the above insights with investment data that have been captured through various sources including research and development and innovation (R&D&I) investments, private equity investment, venture capital investment into new technologies, foreign direct investment and public procurement investment. This data allow for the analysis of the performance of the investment landscape with regard to the twin transitions in the construction industrial ecosystem.

4.1 R&D&I investments

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

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

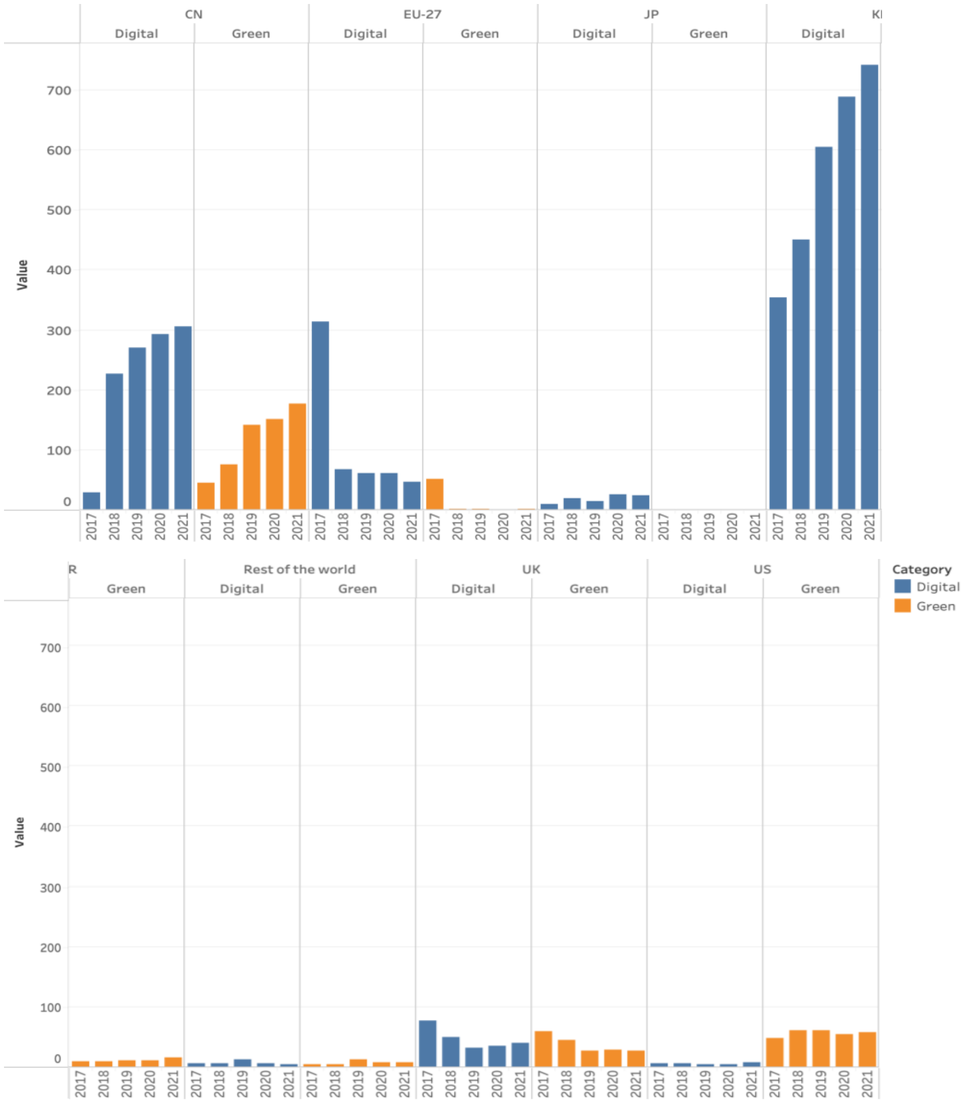
EU27 companies are focussing more on digital technology investment in the construction ecosystem with over €1.8 bn in investments from 2017-2021, whereas green technologies see €441 m over the same time period. Looking at world regions, as depicted in Figure 31, China and South Korea are clearly dominating the R&D&I investment landscape, with increasing trends across the observed period. The EU27 is showing declining trends, especially for digital technologies. The US are also showing important positive trends specifically for the green technologies related to the construction industrial ecosystem. The importance of China and South Korea is explained by the fact that these

[52] European Commission (2023) European Construction Sector Observatory (ECSO) Data mapper https://single-market-economy.ec.europa.eu/sectors/construction/observatory/data-mapper_en

countries have more large construction firms compared to other countries with an average turnover being much higher compared to US and EU companies.

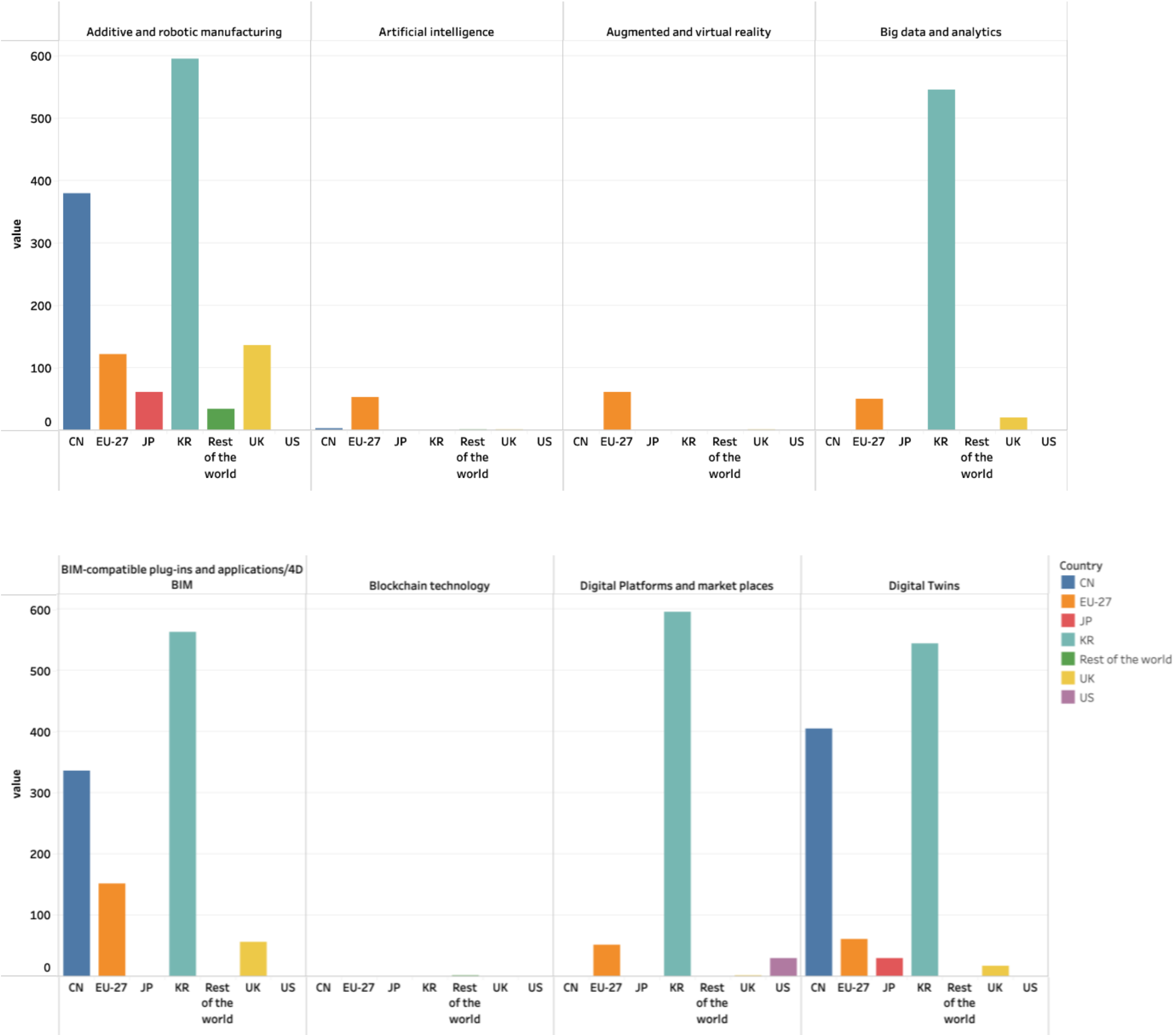
In order to understand which digital technologies are underpinning the global digital technology trends, Figure 32 presents the total R&D&I investments across the EU-27, China, South Korea, Japan and the US over the period of 2017-2021. **Additive and robotic manufacturing, BIM-compatible plug-ins and applications/4D BIM, as well as digital twins stand out as being of global importance** for the observed regions for the construction industrial ecosystem.

Figure 31: R&D&I investments of companies involved in the technologies related to the construction industrial ecosystem by world region (2017-2020)



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

Figure 32: R&D&I investments of companies involved in the digital technologies related to the construction industrial ecosystem from 2017-2020 by world region



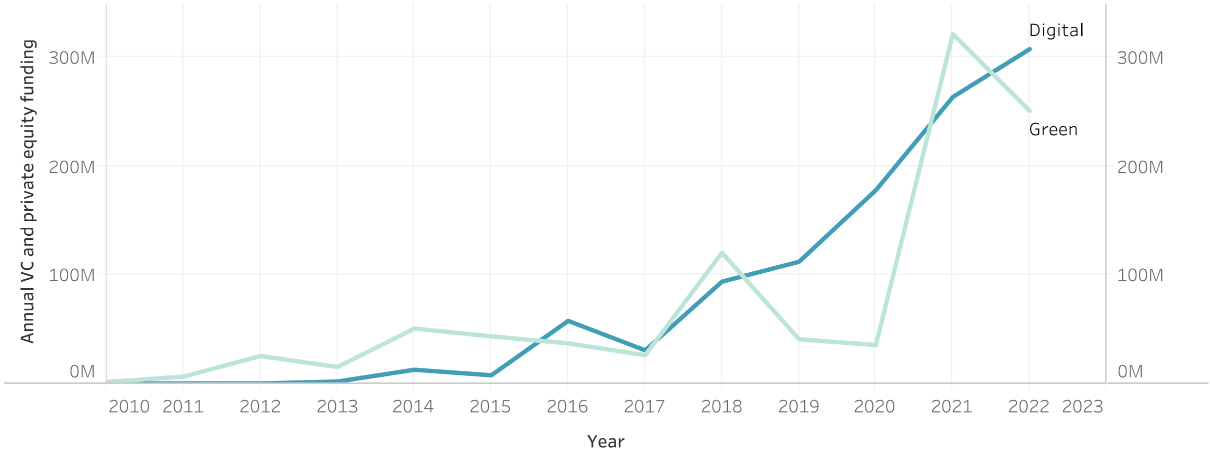
Source: Support to Assessment and Monitoring of Industrial Research, Innovation and Technologies in the field of circular economy industries, 2022, based on ORBIS, Dealroom, PATSTAT and Technote

4.2 Private equity and venture capital investment in construction tech companies

The scale of venture capital and private equity investment in construction tech companies that focus on digital and green technologies and business models has been calculated using a combined data set from Net Zero Insights and Crunchbase sources[53]. Annual investments are captured in the time period from 2010 to 2022 as presented in Figure 33.

The results suggest that the **overall investment both in green and digital construction tech has been increasing over time with digital technologies leading the way in 2022.**

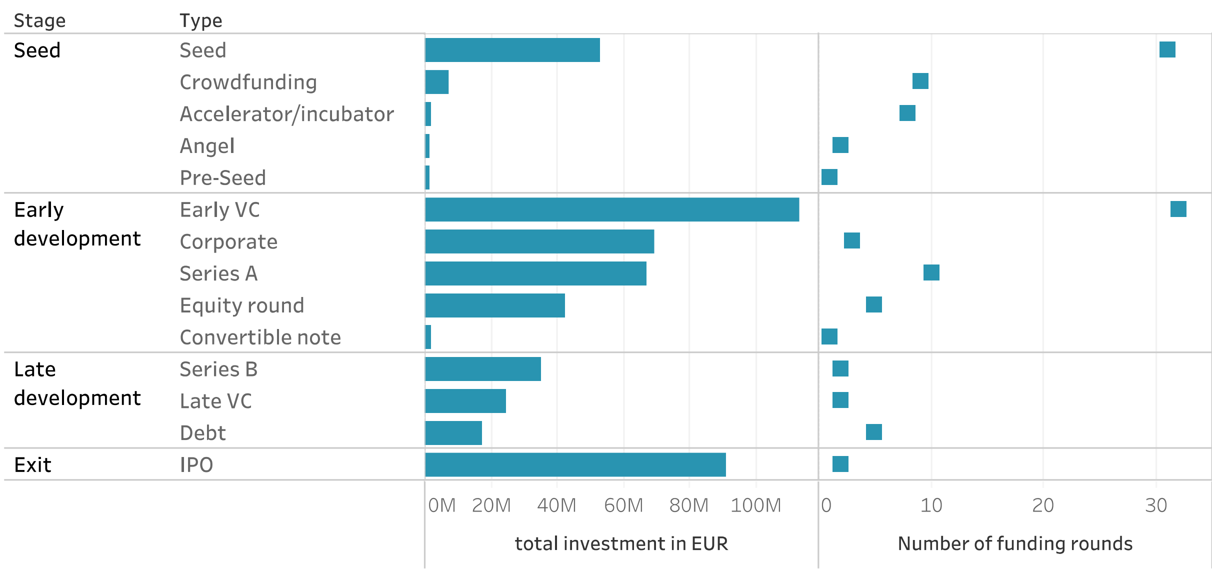
Figure 33 Annual private equity and venture capital investment into green and digital construction tech companies (2010-2022) in the EU27



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

Zooming in on the **innovative green construction tech companies**[54], breaking down the funding by stage into subclasses gives insight into specifically which rounds of funding received the greatest attention over the period 2010 to 2022 (see Figure 34). Over this time period the **greatest amount of funding for green construction tech start-ups goes to early development, notably early VC funding** followed by corporate and series A funding.

Figure 34: Total funding by stage and type of instrument into digital and green construction tech companies in the EU27

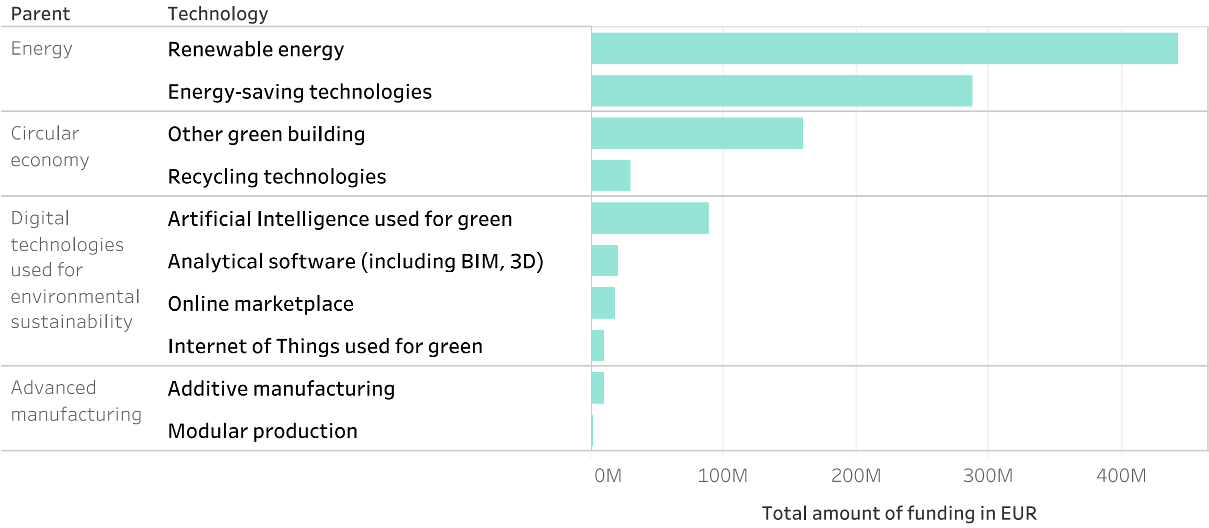


Source: Technopolis Group based on Net Zero Insights and Crunchbase, 2022

[54] The Net Zero Insights and Crunchbase databases focus on technology startups in the green and digital space, respectively. Start-ups related to the construction industrial ecosystems within this pool have been associated to the ecosystem using a set of keywords and tags, that are specific to the ecosystem definition outlined in Chapter 1. Precise terms selected are found in the methodological annex.

The **total funding by type of green technology** is presented in Figure 35. Innovative green construction tech companies in **renewable energy technologies and energy saving technologies** are attracting the highest investments. The leading digital technologies attracting investments for innovative green construction tech companies are artificial intelligence and big data, cloud-based and other software solutions for green.

Figure 35: Total funding (2010-2022) by type of technology applied with environmental sustainability objectives in construction tech startups in the EU27

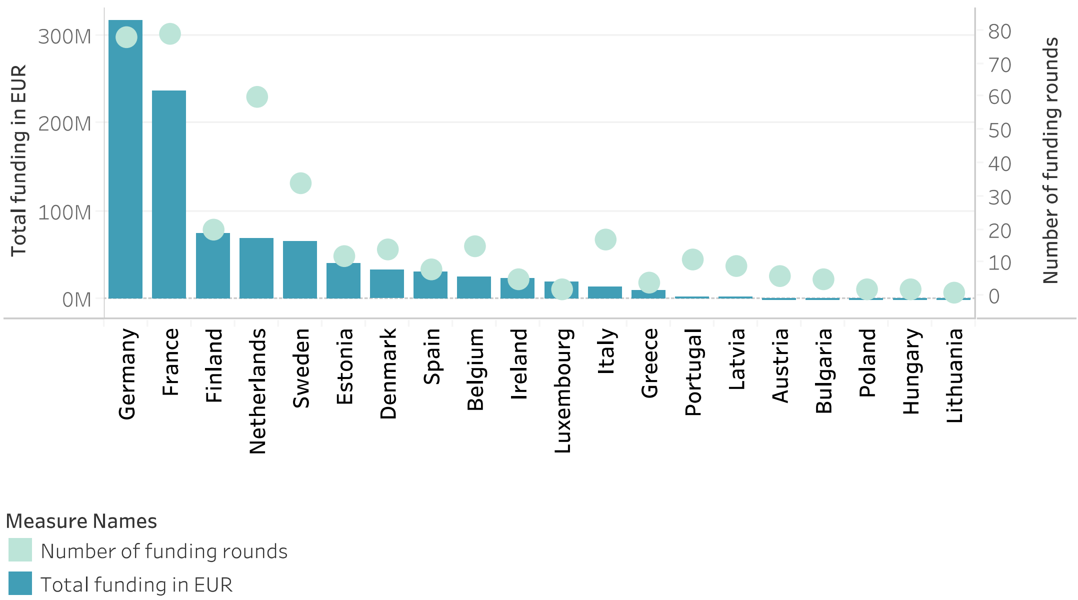


Source: Technopolis Group based on Net Zero Insights and Crunchbase, 2022

Note: Financial data for robotics and blockchain not available

In terms of geography of the innovative green construction tech companies that are receiving the above-mentioned investments, Figure 36 presents the **EU27 countries and their total investments in green construction startups**. **Germany, France and Finland** stand out as having the highest investments headquartered in their country, with France, Germany, the Netherlands and Sweden having the highest number of funding rounds in the EU27.

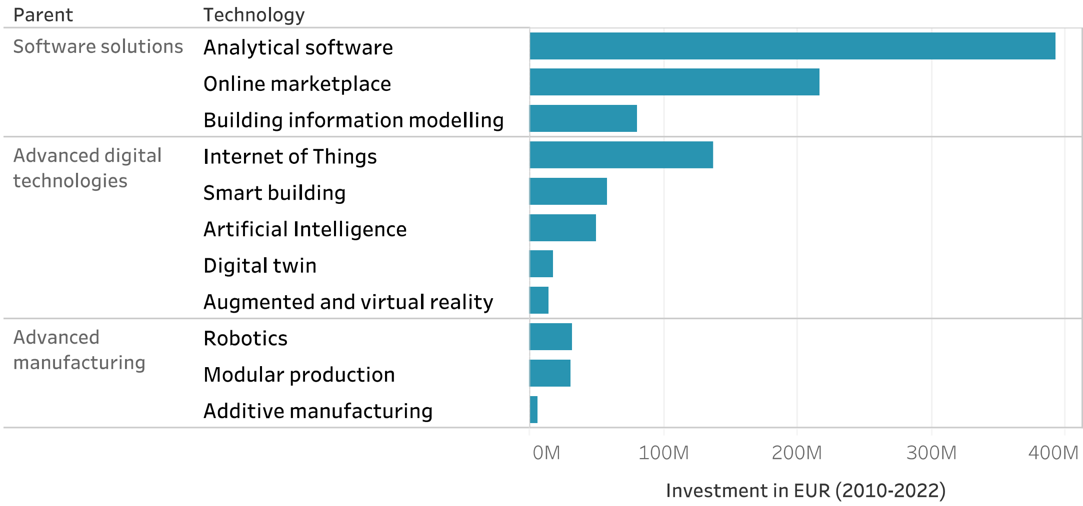
Figure 36: Total investments in green construction tech startups by country



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

Investments in **innovative digital construction tech companies**[55] lie predominantly in the areas of **analytical software services (data, cloud etc)**, as well as **online marketplaces** and **Internet of Things and smart building** with over **€390 m, €215 m, €137 m i**n investments, respectively (see Figure 37). It is also worth noting that **Building Information Modelling, digital twin, and AVR including 3D visualisation tools** received **€110 m** over the period from 2010 to 2022.

Figure 37: Total funding (2010-2022) by type of digital technology in construction tech companies in the EU27

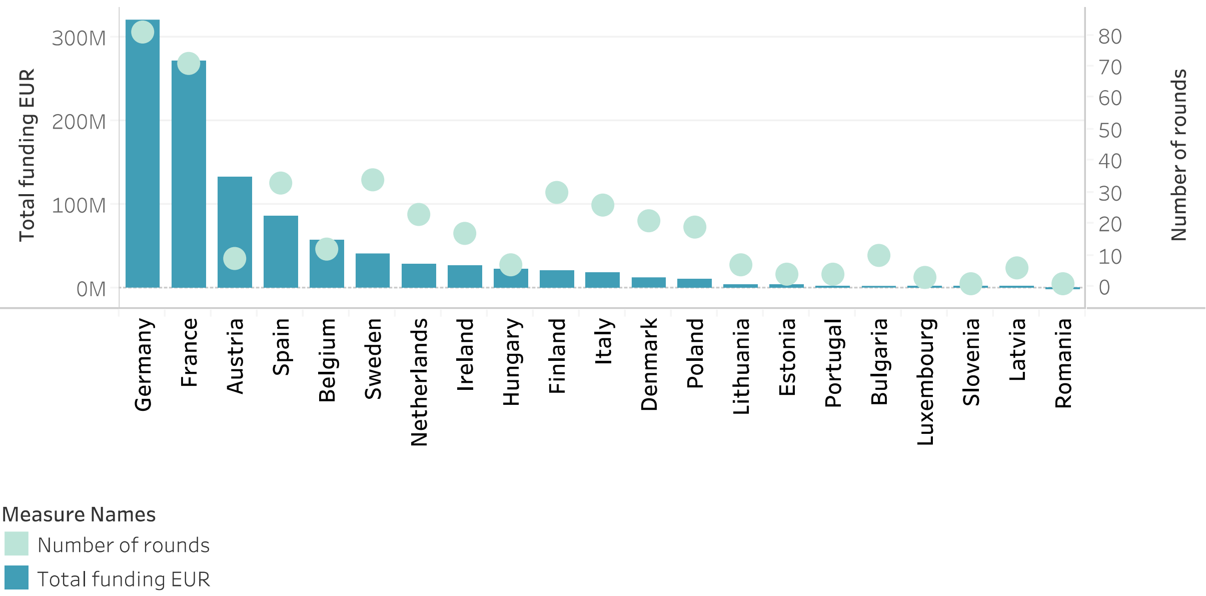


Source: *Technopolis Group based on Net Zero Insights and Crunchbase, 2022*

Looking at geography of the digital construction investments based on the location of the companies invested in, most investments are taking place in **Germany, France and Austria**, with the highest number of funding rounds in Germany, France, and Spain. Further details are found in Figure 38.

[55] The Net Zero Insights and Crunchbase databases focus on technology startups in the green and digital space, respectively. Start-ups related to the construction industrial ecosystems within this pool have been associated to the ecosystem using a set of Tags, that are correlated to the ecosystem definition outlined in Chapter 1. Precise terms selected are found in the methodological annex.

Figure 38: Total investments in digital construction tech startups by country in the EU27



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

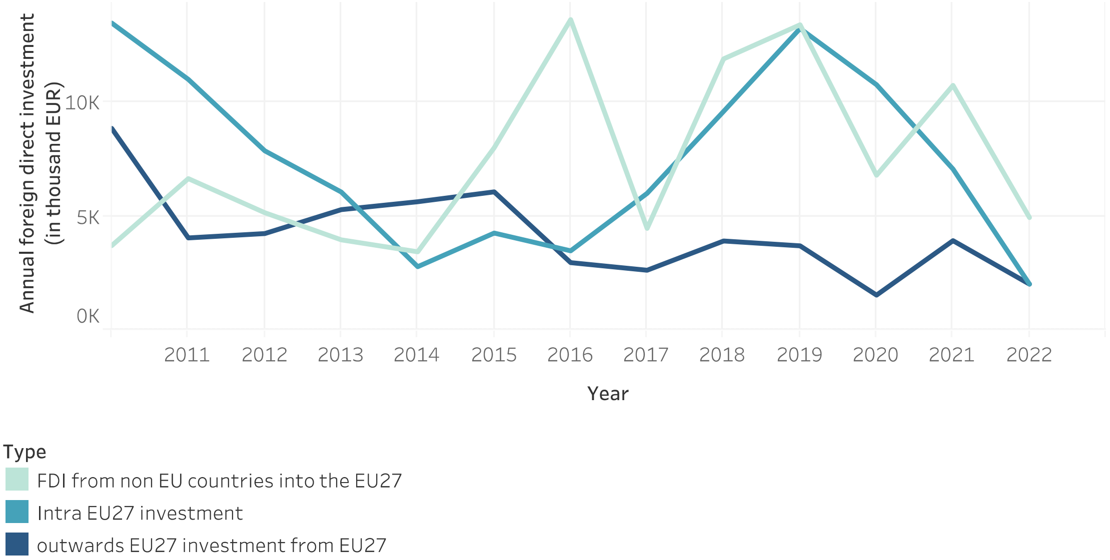
4.3 Intra EU and extra EU foreign direct investment in construction

fDi intelligence[56] tracks cross-border greenfield investment both intra EU, extra EU and globally, covering the **construction industrial ecosystem among other industries. It provides real-time monitoring of investment projects**, capital investment and job creation with powerful tools to track and profile companies that are active investors in the construction industrial ecosystem. The data source tracks projects that are expected to create new jobs and do not cover merges and acquisitions as these are already part of the venture capital data analysis above.

Figure 39 presents the total capital investment over time of foreign direct investment (FDI) construction projects (from EU or to EU). The figure showcases the evolution over time of total capital expenditure of Construction FDI projects from or to EU member states. Three categories of movement are visible: Intra EU (FDI projects from EU27 countries to EU27 countries), foreign direct investment from non-EU countries into the EU27, and outwards EU27 FDI from EU27 countries. The COVID-19 pandemic is evident in the year 2020 across all three indicators, with intra EU27 investments remaining low, also in 2021. FDI from non-EU countries into the EU 27 as well as outward EU27 investment from the EU27 do however recover in 2021.

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

Figure 39: Trends in FDI investment in the EU27 as a source and destination in the construction industry



Source: Technopolis Group based on fDi intelligence, 2022

4.4 Public procurement supporting the digital and green transition of construction

Investments made through public spending, specifically procurement by public authorities are particularly interesting as a data source for construction due to considerable public spending on construction. As regards the twin transition, **the transformative power of public procurement can be used to foster transitions such as digitalisation and greening** by procuring e.g., innovative goods (innovative procurement) and services as well as environmentally friendly (green public procurement) good, solutions, services, among others.

To monitor the twin transition in public procurement, the **procurement notices/awards of relevance to the industrial ecosystem and green and digital products, goods or services** procured have been captured as a part of this indicator. The approach was based on a combination of the Common Procurement Vocabulary (CPV) classification system to outline the construction industrial ecosystem and keywords to describe both the green and digital transition. The main source for this analysis has been the Tenders Electronic Daily, the online version of the 'Supplement to the Official Journal' of the EU, dedicated to European public procurement, which captures information on over 520,000 notices per year across the EU27, amounting to over €470 bn.

As a result of the analysis, **public procurement on construction was valued at a total of over €825 bn between 2015 and 2020**, with over €7.86 bn dedicated to the twin transition (0.95% of the total procurement value (0.82% green, 0.13% digital), and 6% of notices published (4% green and 2% digital). **Procurement data presents a promising opportunity to monitor the twin transitions** in the construction industrial ecosystem, especially the green transition. That being said, Green Public Procurement (GPP) data are underrepresented in this analysis as environmental requirements are often detailed in technical documents, as opposed to evaluation and award criteria, which serve as a basis for this analysis.

Figure 40: The construction industrial ecosystem undergoing twin transitions in public procurement data

Source: Technopolis Group based on the analysis of TED

Zooming in on the green transition, specifically **energy performance, material re-use and the use of photovoltaics made up the most common references** underpinning this transition in the construction industrial ecosystem. Specifically, energy performance is outlined among the evaluation and award criteria, where contractors need to demonstrate previous experience in designing or building a building that has obtained high energy performance certificate ratings. Reuse of materials are typically included as a specification of the materials to be used for construction, whereas photovoltaics are generally mentioned as part of specific solar power projects.

On the digital transition, which is less present in the procurement notices analysed here, **digitalisation and automation** are covered within the umbrella of the **data service provision**, e.g., related to maps or geographic information services provision, and the **installation of advanced technologies** such as in telecommunication towers and fibre optic cables. Automation is also relevant in the presence of hazardous waste, demolition and defence works (e.g., flood protection measures). **Building information modelling (BIM)** is also represented under the digital transition, however the results show that the inclusion of BIM in notices is mostly related to small scale reconstruction and renovation works.

4.5 EU research and innovation funding into construction

In this study, Horizon 2020 funding data was further analysed with regard to digital and green transition related investments within agri-food. Horizon 2020 was the European Union's multiannual research and innovation programme for the period 2014-2020. According to data from the Community Research and Development Information Service

(CORDIS), the programme funded 955 projects classified under the construction industrial ecosystem with a total funding of €3.8 bn in 2014-2020.

The digital and green transition related projects accounted for € 6 957 422 082 bn

Among the funded projects, ICT projects accounted for 71% of the total funding according to the coding available in CORDA[57], followed by nanotechnologies, advanced materials, biotechnology and advanced manufacturing and processing (NMBP) (23%).

Zooming in on the technologies as defined in the Methodological Report of the Monitoring industrial ecosystems (EMI) project, Table 2 outlines the total cost per technology related to the construction industrial ecosystem. With more specific technologies such as additive and robotic manufacturing technologies (16%) and advanced manufacturing (ICA and Mechanical Engineering) & robotics (16%) making up important segments in terms of technological focal areas. Moreover, the use of artificial intelligence technologies and internet of things are also relevant having accounted 11% each of the total funding.

Table 1: CORDA EU R&I funding in EUR in constrution - High level technology area coding

Technology - High level (coded in CORDA)	**Total Cost**	**FP Contribution**	**Other investement**	**Share in total (using Total cost)**
Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy	996,056	50,000	946,056	0%
ICT	7,606,146,034	3,930,872,516	3,675,273,518	71%
Nanotechnologies, Advanced Materials, Biotechnology and Advanced Manufacturing and Processing (NMBP)	2,466,658,170	2,130,773,612	335,884,558	23%
Smart, green and integrated transport	141,597,923	17,133,023	124,464,899	1%
Total	10,215,398,182	6,078,829,151	4,136,569,032	95%
TOTAL CONSTRUCTION	10,720,766,071	6,483,115,398	8,273,138,063	100%

Source: Technopolis Group based on CORDA, 2022

[57] CORDA data is a private version of CORDIS data. It includes the NACE code of the beneficiaries, therefore allowing to a sector-based analysis.

Table 2: CORDA EU R&I funding in EUR in construction – Technology based classification

Technology & IE (scivoc based)	Total Cost	FP Contribution	Other investement	Share in total (using Total cost)
Air pollution engineering	241,401,699	114,500,962	126,900,737	1%
Additive and robotic manufacturing	2,663,227,734	1,614,029,311	1,049,198,423	16%
Artificial Intelligence (& Machine Learning & Computational intelligence)	1,710,132,904	852,768,094	857,364,810	11%
Smart Cities	343,707,042	251,164,395	92,542,647	2%
Sustainable building	341,120,219	294,901,531	46,218,688	2%
Sustainable economy	573,432,251	412,879,200	160,553,050	4%
Home automation	348,201,744	245,725,222	102,476,522	2%
Advanced Manufacturing (ICA and Mechanical Engineering) & Robotics	2,513,258,341	1,449,032,408	1,064,225,934	16%
Artificial Intelligence (& Machine Learning & Computational intelligence)	1,710,132,904	852,768,094	857,364,810	11%
Digital Security & Networks/ Cybersecurity	126,015,759	91,033,872	34,981,887	1%
Digital Tech for Mobility	1,164,794,577	784,818,952	379,975,625	7%
Internet of Things	1,399,422,514	819,723,461	579,699,053	9%
Micro- and Nanoelectronics & Photonics	746,913,378	223,229,346	523,684,032	5%
Biotechnology including Medical Biotechnology	210,650,005	130,272,199	80,377,805	1%
Hydrogen technologies	183,833,090	60,245,193	123,587,897	1%
Wind, Solar and other (geothermal, hydropower, biomass) Power	1,355,511,355	705,813,365	649,697,990	8%
Recycling technologies relevant for the circular economy	342,823,546	299,907,337	42,916,209	2%
TOTAL	16,181,808,924	9,386,018,538	6,795,790,386	100%

Source: Technopolis Group based on CORDA, 2022

5. Skills

Key findings

Due to an **ageing workforce**, the construction industrial ecosystem needs to urgently **improve its attractiveness** to younger workers. The **processes of constructing buildings are becoming increasingly digital** in their operation requiring more digital skills in the existing workforce. At the same time, as architects and engineers work to improve the environmental impact of buildings, **construction workers need to acquire the necessary green skills to implement the sustainable buildings of the future.**

6.6% of the professionals working within the construction industrial ecosystem and with a profile on LinkedIn reported at least **one skill relevant for the green transformation**, and **18% at least one digital skill.**

Skills in **energy saving technologies** and **low carbon** lead the way for the green skills at 1.29% and 1.28% of professionals within the total construction industrial ecosystem, respectively. Skills in **advanced manufacturing** dominate the digital skills domain at 15.11% of the professionals working in the construction industrial ecosystem.

Software tools such as AutoCAD and Adobe Photoshop stand out, with variations thereof also represented such as other CAD and visualisation tools. In addition, **Building Information Modelling (BIM) are also evident** among the top self-identified skills for the construction industrial ecosystem.

Soft skills, such as those related to commercialisation, process improvement, overall technical support and creativity skills are growing in importance across the ecosystem, however other technical skills in data tools such as **REVIT, BIM and ARCHICAD remain important** with steady growth between 10.6%, 12.4% and 12.6% percent growth from 2021 to 2022, respectively.

Greece, Cyprus, Ireland, Denmark and Slovenia are important countries for the green skills underpinning the construction industrial ecosystem. Greece, Cyprus, Croatia, Slovenia, and Italy concentrate the highest shares of digital skills professionals for the construction industrial ecosystem.

The construction industrial ecosystem is faced with various challenges related to its underlying workforce as well as the skills needed for the future transformation of the industrial ecosystem. With an ageing workforce, the construction industrial ecosystem needs to urgently improve its attractiveness to younger workers in the face of pending retirement of existing workers. At the same time, lifelong learning in the face of new and future skills needs requires attention. The process of constructing buildings are becoming increasingly digital in their operation, relying on the use of drones, augmented and virtual reality, but also big data and internet of things installation require more digital skills in the existing workforce. At the same time, as architects and engineers work to improve the environmental impact of buildings, construction workers need to acquire the necessary green skills to implement the sustainable buildings of the future.[58]

This section aims at analysing trends in the supply and demand of skilled professionals relevant for the **green and digital transition based on LinkedIn data**. 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 and both in digital and green transition. It represents the single most comprehensive source currently available for the construction

[58] European Commission (2021). Scenarios for a transition pathway for a resilient, greener and more digital construction ecosystem

of technology-specific skills related indicators. To capture the construction industrial ecosystem the **'Construction', 'Architecture & Planning' and 'Civil Engineering' categories** have been used. In order to capture the number of professionals working in the sector, occupations related to the industrial ecosystem have been taken into account.

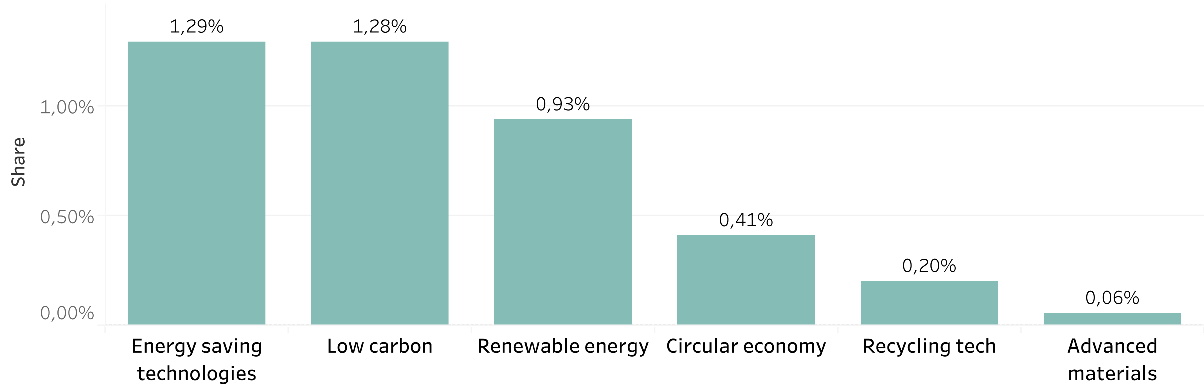
5.1 Green and digital skills

Green skills have been identified as skills related to environmental protection, environmental services, low carbon technologies, renewable energy, the circular economy and clean production technologies and business models related skills.

Digital skills have been defined in the context of the main digital technologies captured in this project notably in artificial intelligence, cloud computing, connectivity, robotics, Internet of Things, augmented and virtual reality and blockchain.

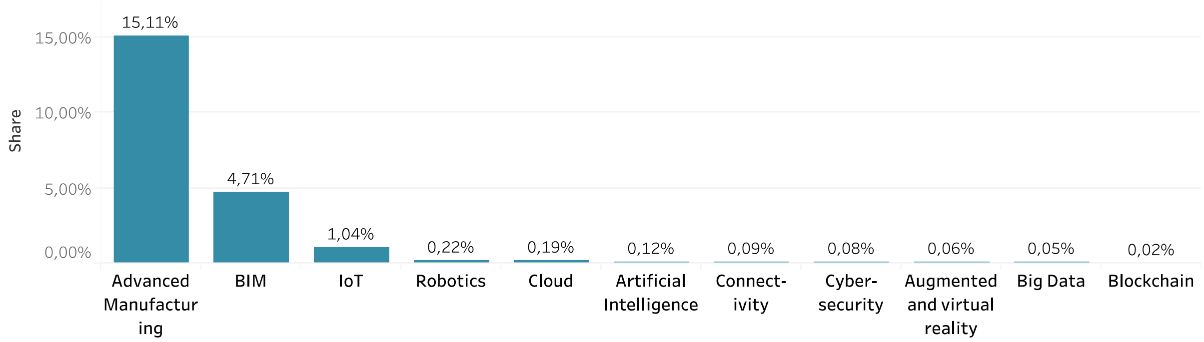
Based on the analysis of LinkedIn data, **6.6% of the professionals working within the construction industrial ecosystem and with a profile on LinkedIn reported at least one skill relevant for the green transformation, and 18% at least one digital skill**. Figure 41 details the breakdown for the green skills, whereby skills in energy saving technologies and low carbon lead the way for the green skills. Figure 42 provides a more detailed picture of the supply of professionals with specific digital skills within the construction industrial ecosystem in 2022, notably advanced manufacturing and BIM stand out.

Figure 41: Share of professionals with green skills within the total number of professionals working in the Construction industrial ecosystem with a profile on LinkedIn



Source: Technopolis Group calculations based on LinkedIn, November 2022

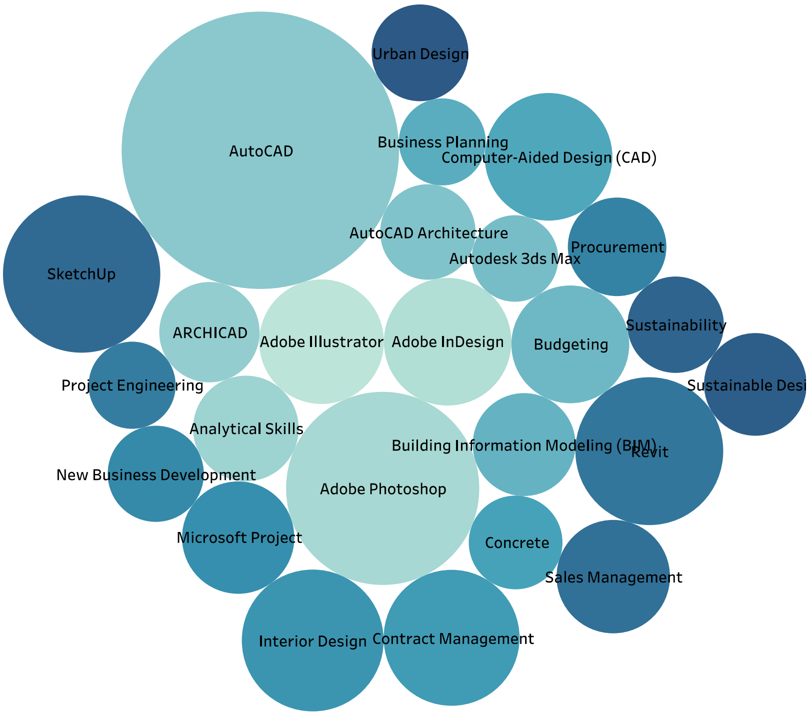
Figure 42: Share of professionals with digital skills within the total number of professionals working in the Construction industrial ecosystem with a profile on LinkedIn



Source: Technopolis Group calculations based on LinkedIn, November 2022

Drawing up on the LinkedIn skills classification, Figure 43 presents the self-indicated skills by professionals registered on LinkedIn related to the construction industrial ecosystem. The size of the bubble corresponds to the importance of the skills across the construction, architecture, and civil engineering domains. **Software tools such as AutoCAD and Adobe Photoshop stand out,** with variations thereof also represented such as other CAD and visualisation tools. In addition, **Building Information Modelling (BIM) are also evident among the top self-identified skills for the construction industrial ecosystem**.

Figure 43: Most common skills among professionals working in construction, architecture, and civil engineering with a profile on LinkedIn



Source: Technopolis Group calculations based on LinkedIn, November 2022

Reflective of the fact that architecture and civil engineering are included within the overall ecosystem definition, architects are the most dominant position mentioned for both green and digital skills as a percentage of the total persons registered to the construction industrial ecosystem. Engineers are also the second and fourth most common job title for the digital and green transition.

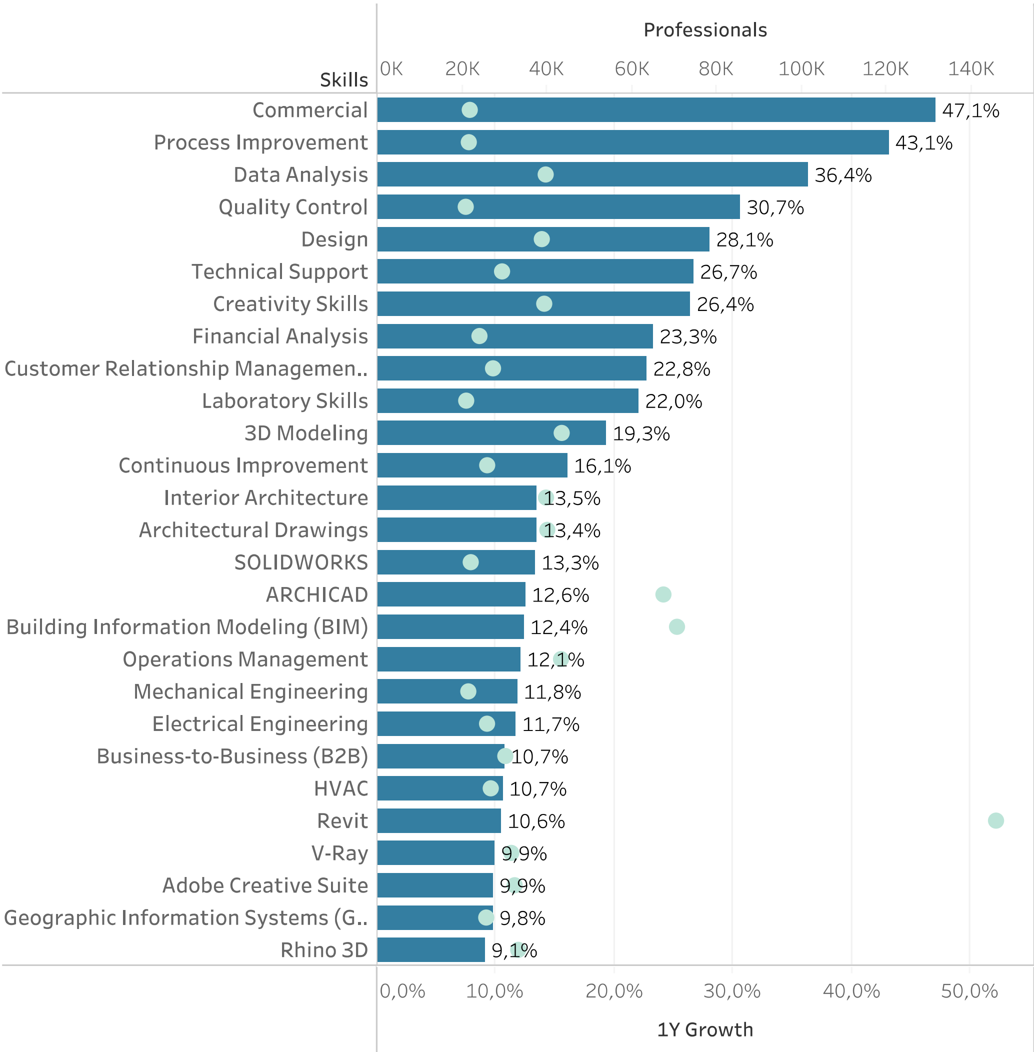
Progress over time

It is also interesting to present the evolution of skills developments in the construction industrial ecosystem over time. Overall, the **total number of professionals in the construction ecosystem with a profile on LinkedIn has stayed more or less stable** over time (0.4% increase from 2021).

There have been 7% more professionals in the construction industrial ecosystem claiming to have a digital transformation skill and 4% more with a green transformation skill in 2022 than in 2021. In a broader context, available Eurostat figures show that the number of ICT specialists in the EU in the construction sector remain low, with 8% of construction companies employing ICT specialists (compared to 19% EU average). Discrepancies are wide across the EU27, with 80% of companies in Member States from Romania to Sweden struggling to fill ICT specialist positions in the construction sector, which is however not shared to the same degree by companies in Spain, Portugal, and Slovakia.[59]

Figure 44 highlights the strongest growing skills within the construction industrial ecosystem relying on the LinkedIn classification of skills. Blue bars represent the growth rate, with light blue dots indicating the total number of professionals with the indicated skills in order to relativize the importance of certain skills growth rates compared to the overall size. **Soft skills, such as those related to commercialisation, process improvement, overall technical support and creativity skills** are growing in importance across the ecosystem, however other technical skills in data tools such as **REVIT, BIM and ARCHICAD remain important** with steady growth between 10.6%, 12.4% and 12.6% percent growth from 2021 to 2022, respectively.

Figure 44: Strongest growing skills within the construction industrial ecosystem (2021 to 2022)



Source: Technopolis Group calculations based on LinkedIn, 2022

[59] European Commission (2021). Digitalisation in the construction sector https://single-market-economy.ec.europa.eu/document/download/3ae8a41e-4b82-4150-968c-1fc73d1e2f61_en

5.2 Skills demand

Skills demand in the Construction industrial ecosystem has been analysed following the skills intelligence insights of Cedefop. This dataset covers the EU27 countries (plus UK) and is based on the collection and analysis of more than 530 online job advertisement sources (424 distinct websites) which are open-access sites. The dataset provides information on most requested occupations and skills across European countries based on established international classifications, e.g., ISCO-08 for occupations, ESCO for skills, and NACE rev. 2 for sectors.

Specific to the construction industrial ecosystem[60], **there were 7 488 659 unique job advertisements from companies between 2019-2022 in the EU.** The number of online job advertisements within construction in EU27 countries amounts to 2 307 836 in the year 2022. Skills have been analysed related to the green and digital transitions. The green pre-defined skills are from ESCO v1.1 and the digital are predefined from ESCO v1.1.1 which is currently being updated.

- Green skills: The labelling of skills and knowledge concepts as green follows a methodology based on a 3-step process, which combines human labelling and validation, and the use of Machine Learning (ML) algorithms: 1) Manual labelling; 2 Machine learning classifier; 3) Comparison and manual validation.
- Digital Skills: The labelling of skills and knowledge concepts follows a 5-steps methodology, which combines human labelling and validation with the use of Machine Learning (ML) algorithms. 1) label manually; 2) Create training dataset; 3) Train ML classifiers; 4) label automatically; 5) Compare the labels.

Online job advertisements that can be related to the twin transition in 2022 amount to 1 118 073 which represents 48% of total online job advertisements. However, when disregarding basic digital skills, the share of related green and digital transition online job advertisements drops to 31.31%.

The top digital skills including both general and more advanced digital skills that appeared most often in construction job advertisements over the period from 2019-2022 the following:

- Computer programming
- Technical drawings
- Database
- Business ICT systems
- Automation technology
- SQL
- Hardware components
- Cloud technologies

The green skills are significantly more limited compared to digital. The more sought-after green skills are:

- Energy efficiency
- Environmental legislation
- Corporate Social Responsibility

[60] In the case of the construction industrial ecosystem the dataset was filtered for the NACE industries as defined in the Annual Single Market Report for construction

- Environmental engineering
- Energy performance of buildings
- Solar energy
- Emission standards

6. Sustainable competitiveness: green performance of the ecosystem

Key findings

The construction industrial ecosystem is remarked for its clear and increasing environmental impact, ranging from the material extraction required for construction to the land that is sealed as a result of construction activities and the emissions from construction production and activities.

In terms of resource utilisation, **land use and water consumption show increasing trends for the construction industrial ecosystem associated with increasing environmental impact**. At the same time materials consumption shows a slightly decreasing trend, initially positive, this could also be attributed either to decreasing extraction post COVID-19, related to supply chain challenges or to a shifting of materials extraction outside of the EU-27.

In terms of direct environmental impact, **increasing trends in global and local emissions related to the construction industrial ecosystem are evident in recent years**, following significant decreases in previous years. Ecosystem damage is on the rise, with **increasing biodiversity loss** associated with the activities of the construction industrial ecosystem.

Construction and construction works are **among the three highest products in terms of CO_2 emission footprint**, where values remain relatively constant between ca. 750 and 710 kilograms per capita of CO2 equivalent emissions between the years of 2014 and 2019, with a slight downward trend in the recent years (2018-2019).

6.1 Green performance

The construction industrial ecosystem is remarked for its clear and increasing environmental impact, ranging from the material extraction required for construction to the land that is sealed as a result of construction activities and the emissions from construction production and activities. Also building renovation, while necessary in the long term, first requires further resources and generates impact before leading to potential energy savings and efficiency gains.

As a resource intensive industrial ecosystem, time series on **resource use in the construction industrial ecosystem** are particularly interesting to examine. Various data set are in place that can capture certain elements of the environmental impact of the industrial ecosystem. With the aim to measure the trends in the above-mentioned environmental impacts, this report draws upon the **data sources of Eurostat and Exiobase**. The green transition impacts are sourced from Eurostat and Exiobase 3.8[61]. Whilst Eurostat represent the official statistics, Exiobase is a legitimate source of information referred to for example by the European Environmental Agency[62], the EC/JRC

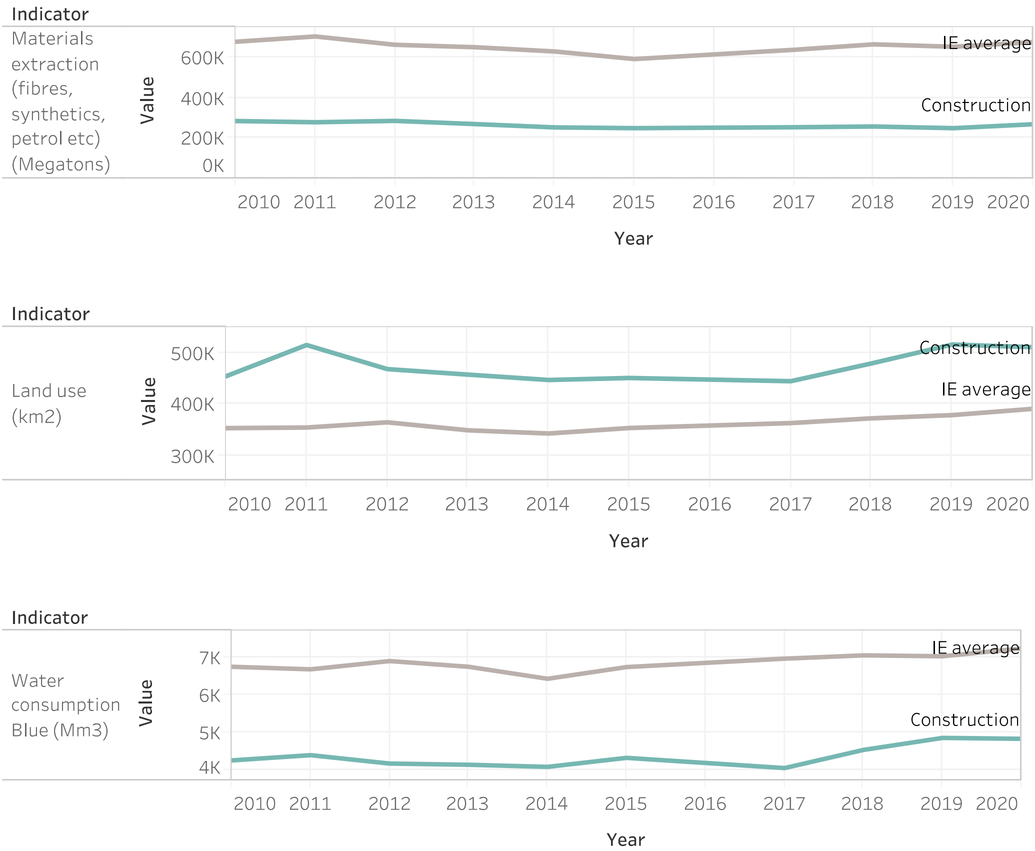
[61] Exiobase is a time series of environmentally extended multi-regional input-output (EE MRIO) tables. Its coverage is by country and industry from 1995 to 2021 and has EU and extra rest of the world coverage. Source: Stadler, Konstantin, Wood, Richard, Bulavskaya, Tatyana, Södersten, Carl-Johan, Simas,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

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

community[63], Eurostat[64], and by the European Commission to propose the regulation on carbon border adjustment mechanisms[65]. Pressure to environments refer to trade-embodied resources utilisation, and trade-embodied impacts.

Resource utilisation is captured along four main dimensions for cross-industry comparisons: (i) embodied land use, (ii) embodied water consumption[66], and (iii) embodied materials consumption supplied to the industrial activity. Figure 45 highlights that land use and water consumption show increasing trends, associated with increasing environmental impact, where materials extraction is slightly decreasing. The latter can be attributed to increasing shifts towards materials imports within the EU27 for use in the construction industrial ecosystem.

Figure 45: Resource use for the construction industrial ecosystem in the EU27



Source: Technopolis Group, 2022, based on Exiobase data

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

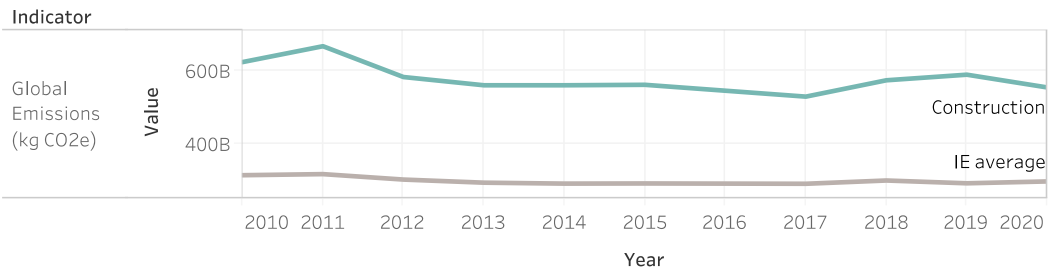
[64] Remond-Tiedrez, I. and Rueda-Cantuche, J.M. eds., 2019. EU Inter-country Supply, Use and Input-output Tables: Full International and Global Accounts for Research in Input-output Analysis (FIGARO). Luxembourg: Publications Office of the European Union.

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

[66] Blue water consumption is water sourced from surface or groundwater resources incorporated into a good, used for a service, or returned to another source after the good or service has been produced, or returned at a different time. The annual volume in Million cubic meters comes from the Exiobase 3.8.2 consumption-based account. This account estimates the trade embodied impacts of domestic industrial activities and international trade (exports and imports). It therefore estimates the blue water consummption as a consequence of the ecosystem's complex international supply chain forward and backward.

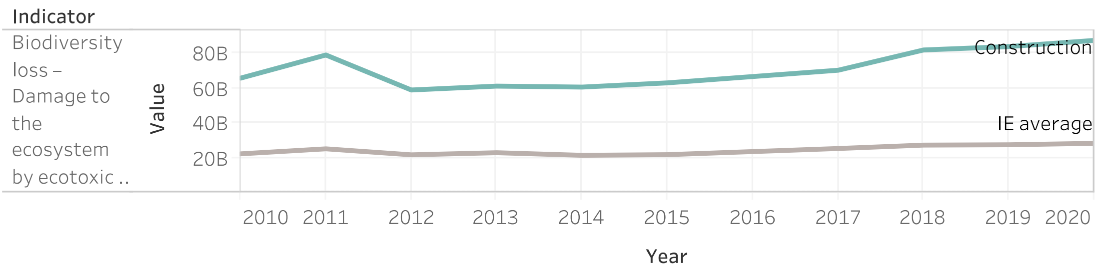
In terms of impacts, there are two dimensions to be looked at, notably: **Air emissions** (incl. GHG) and **damage to the ecosystem**. Figure 46 presents both global emissions, in megatons of CO_2 equivalent, as well as local emissions, focussing rather on particulate matter emissions such as PM10 and PM25. In both cases increasing trends are evident in recent years, following significant decreases in the year from 2011 to 2012. **Ecosystem damage**, presented in Figure 47 covering **biodiversity loss, is seeing a clear increase** since a drop in 2012, with an increased danger to extinction of species as a consequence of the construction industrial ecosystem and its activities. The unit of measure refers to the globally potentially disappeared fraction of species over time (PDF).

Figure 46: Greenhouse gas emissions for the construction industrial ecosystem in the EU27



Source: Technopolis Group, 2022, based on Exiobase data

Figure 47: Biodiversity loss – damage to ecosystems related to the construction industrial ecosystem expressed in million globally potentially disappeared fraction of species over time (PDF) in the EU27



Source: Technopolis Group, 2022, based on Exiobase data

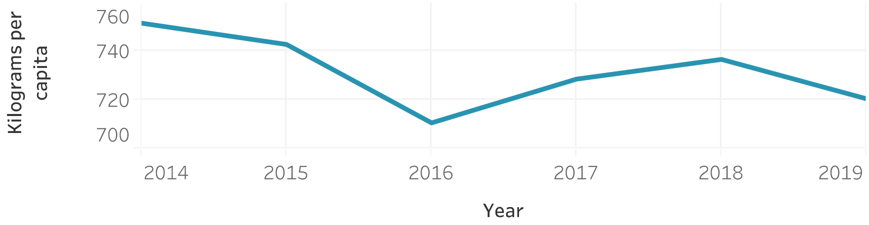
Captured by Eurostat estimates, **carbon footprint data** are presented for 'Construction and construction works' representing the carbon dioxide (CO_2) emissions equivalent associated with final use of products.[67] The approach relies on modelling of economic information together with air emissions accounts, which are based on estimates. Specifically, the CO_2 equivalent captures greenhouse gases CO_2, N_2O in CO_2 equivalent, CH_4 in CO_2 equivalent, HFC in CO_2 equivalent, PFC in CO_2 equivalent, SF_6 in CO_2 equivalent, and NF_3 in CO_2 equivalent. Modelled data are based on estimates. The results are presented as complementary to the air emissions information presented in the above based on Exiobase data.

Comparatively, **construction and construction works** as a pre-defined category **is among the three highest products in terms of CO_2 emission footprint**, together with electricity, gas steam and air conditioning and food, beverage and tobacco products. Figure 48 presents the results extracted from the Eurostat database, where values remain relatively constant between ca. 750 and 710 kilograms per capita of CO2 equivalent

[67] Eurostat (2022) Greenhouse gas emission statistics - carbon footprints, see: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Greenhouse_gas_emission_statistics_-_carbon_footprints#Carbon_dioxide_emissions_associated_with_EU_production

emissions for construction and construction works between the years of 2014 and 2019, with a slight downward trend in the recent years (2018-2019).

Figure 48: CO_2 equivalent emissions due to final use, EU27, 2014-2019 (kg per capita)



Source: IDEA Consult based on Eurostat [env_ac_io10]

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Appendix B: Methodological notes

Startup data and venture capital data analysis

Selected fields from Crunchbase and Net Zero Insights: Architecture, Construction, Smart Home, Smart Building, Real Estate, Green Building

Survey

The table below presents the overview of the sub-sectors included in the sampling frame, with corresponding sections according to the NACE industrial classification.

Table 3 Survey sampling

NACE		Sample size of the survey
F	Construction	681
M71	Architectural and engineering activities; technical testing and analysis	210
N81	Services to buildings and landscape activities	112

Source: Technopolis Group and Kapa Research, 2023

Foreign direct investment data analysis

Selected fields from FDI included:

- Industrial building construction
- Commercial & institutional building construction
- Residential building construction

CORDIS data analysis

LinkedIn data analysis

Selected fields from LinkedIn included:

- Construction
- Architecture & Planning

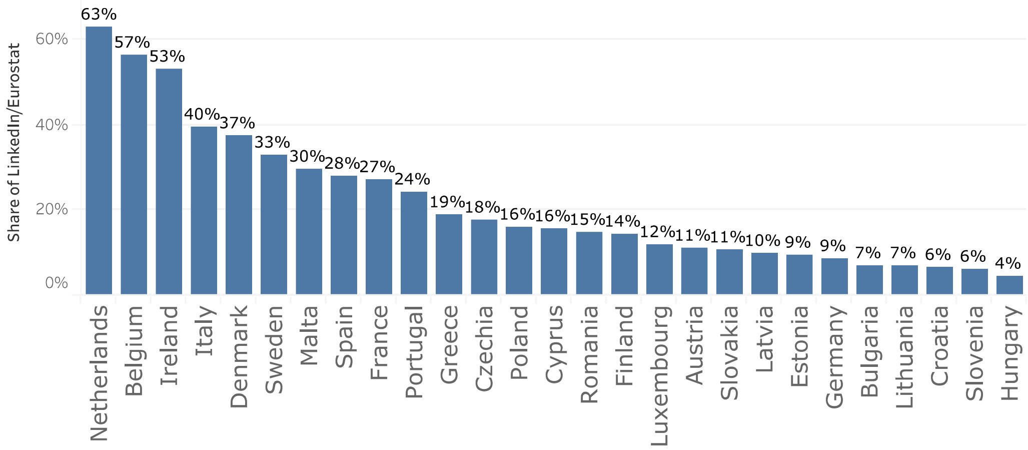
Green skills – keywords used: Cleantech, Sustainability, Sustainable Development, Sustainable Business, Energy Efficiency, Clean Energy Technologies, Renewable Energy, Wind Energy, Biomass, Biomass Conversion, Solar Energy, Solar Power, Urban Forestry, Forest Ecology, Sustainable Communities, Organic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

Representativeness of LinkedIn data. In November 2022, there were 3 659 017 professionals employed in the Construction industrial ecosystem including construction (2 380 902), architecture (742 067) and civil engineering (536 048), located in the EU27 and registered on LinkedIn.

When we compare the number of the Construction sector profiles on LinkedIn with the Eurostat Structural Business Statistics Annual detailed enterprise statistics for construction (last data available from 2018), we get some impressions about the representativeness of the LinkedIn sample). The comparison shows that some countries as the Netherlands, Belgium or Ireland included a larger share of the estimated total workers while other countries are not at all representative in this sector.

Figure 49: Share of the number of LinkedIn users with a profile registered in the industry 'Construction' and the number of Employees in Construction as captured by Eurostat



Source: Technopolis Group based on LinkedIn and Eurostat, SBS Annual detailed enterprise statistics for construction (NACE Rev. 2, F) (online data code: SBS_NA_CON_R2)

There is however a need for a lot of caution when interpreting the above figures. First, there is a difference between the official statistical information available about the persons employed in the Construction sector and the taxonomy of LinkedIn regarding Construction. In LinkedIn profiles of registered professionals and companies are attributed to a certain sector such as 'Construction' based on the self-selection of core industry by the registered members themselves on the one hand and there is also an algorithm cleaning up the missing information on the other hand. Our assessment after checking some of the profiling is that people who claim to work in the Construction sector, do so and the overall attribution is correct. Differences also come from the fact that LinkedIn in general is more of a target for professionals with higher educational attainment. In the Construction sector, this means that managers and engineers with a profile on LinkedIn are better represented on this platform compared to professionals with lower level of education.