Monitoring industrial ecosystems

HEALTH

Analytical report – 2024 edition

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Green Transition

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

-**The health industrial ecosystem has made progress in reducing its emissions footprint, but it continues to face significant challenges in other environmental areas**. In particular, the sector still lags in its impact on water usage and waste reduction. These issues highlight the need for further improvements in the health ecosystem. However, in parallel, it is important to recognise that **the most effective way of reducing the emissions and improve sustainability is reducing the need or demand for healthcare services among the public in the first place**.

-Overall, the health industrial ecosystem **made progress towards the green transition, particularly in the areas of material and energy conservation**. However, the ecosystem still faces challenges in other key areas, such as water conservation and the adoption of circular business models.

-The report highlights the industry's prioritisation of resource efficiency and waste optimisation as part of its green transition efforts. **The most widely adopted environmental measure among health companies in 2024 was minimising waste**, **implemented by 92% of respondents of the EMI Enterprise survey.** This was followed closely by material-saving initiatives, adopted by 82% of companies, and recycling efforts, embraced by 65%. Additionally, 61% of health companies focused on energy saving within their operations.

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

-The investments of companies in the health ecosystem are rather limited, as most **companies (44%) surveyed invest only between 1 and 5% of annual turnover in environmental technologies.** There is also limited investment in green technologies within the health ecosystem when looking at public funding from the European commission. **In Horizon 2020 - 10.19% of health project funding was dedicated to green transition**. For Horizon Europe, considering the projects funded between 2022 and 2024, **only 6% of the funding** to health projects contributes to the green transition.

-The development and **implementation of green skills is essential for the success of the health industrial ecosystem** in this new era, as dealing with different green skills has become a daily practice. The lack of specific green skills has been identified as one of barriers to the green transition in health and there is a lack of dedicated training opportunities on sustainability, which further hampers the situation. However, still a very low percentage of jobs in the health industrial ecosystem in the EU require green skills. Especially important are the skills related to waste management, sustainable building designs (i.e. 0 emission buildings) and climate-resilient healthcare delivery. This is also reflected by the Cedefop data, according to which the share of online job advertisements requiring skills related to the green transition in 2023 was only around 2%.

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

- The **health industrial ecosystem keeps on facing** significant environmental challenges. In particular, the sector **still lags behind in addressing its impact on water usage and waste reduction.**

- In 2020, **the contribution of health ecosystems to greenhouse gas (GHG) emissions was 4.6%**, corresponding to 27.6 megatons, which is an increase from **3.7% in the previous year.**

- Some **EU countries are participating in global initiatives to develop a clear understanding of GHG emissions within their health industries and to formulate specific plans for more sustainable practices in the health industrial ecosystem**.

- The demand for **water, which is a key input for health-related industries, remains particularly high, with consumption levels between 26 and 28 Mm3 since 2020.** Its recovery and recycling require further enhanced management strategies.

Digital Transition

What is the progress of industrial efforts towards digitalisation?

-Digital transformation of the health industrial ecosystem is a key priority for policy makers in the EU. This is embodied by the EU's Digital Decade policy programme or the initiative of the WHO European regions who developed a **European regional digital health action plan for 2023-2030.** This is also shown at the national level, over 80% of EU countries that have a digital health strategy with a strong priority on data access, reuse and information sharing, and now all members states have public funding available for digital health programmes.

-**In terms of advanced digital technologies, the health industrial ecosystem is making good progress towards the target** set by the European Commission in line with the Europe's Digital Decade targets for 2030. Within advanced technologies, cloud computing is particularly important for the healthcare industry with over half of the companies surveyed reporting its use. There has also been an increase in the adoption of Artificial Intelligence (AI) and Internet of Things (IoT) in 2024, with just under a third of companies reporting their use. Among the advanced digital technologies used by startups in the healthcare system, AI technologies is clearly predominant.

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

-In terms of technological trends, patent data **shows that between 2016 and 2019, the share of digital patents has remained stable at around 8.5%.** Micro- and nanoelectronics, photonics, as well as advanced manufacturing technologies and robotics, are the leading technology groups in the health industrial ecosystem in terms of patenting activities from 2010 to 2020. Recent years have shown **an increase in patenting activities for advanced manufacturing and robotics, while micro- and nanoelectronics and photonics saw a decline**.

-**For investments in advanced digital technologies in the health sector, they are focused first on big data, robotics, cloud computing and edge computing where over 75% of companies reported an investment between 1% and 10% of their annual turnover.** For Big Data 25% of businesses surveyed aim to invest 6-10% of their turnover in the technology. For robotics over 22% or in cloud computing 21% of businesses surveyed aim to invest 6-10% of their turnover in these technologies. For AI technologies, just over 55% of businesses are planning in investing between 1 and 10% of annual turnover in this technology.

-In terms of venture capital investments, **most investments are directed toward AI startups, with substantial annual investments ranging from €190 m to €380 m since 2021. Public investments in Horizon 2020 and Horizon Europe** have shown that the share of digital transition projects has remained stable between the two programmes up to date, with around 40% of projects focusing on the digital transition in the health ecosystem.

-In terms of digital skills, there is a policy push towards digital skills at the EU level, where the European Year of Skills, and the Pact for Skills have set an ambitious target of 10% of health professionals that should participate in reskilling and upskilling in digital skills annually by 2030 (representing 1.5 million of workers per year). This is a significant challenge since health and care workers represent over 4% of the EU population. In terms of digital skills demand of the healthcare system, **an analysis of job advertisements (using Cedefop data) shows that 36% of job advertisements in the health industrial ecosystem require digital skills.**

What is the impact of digital technologies on competitiveness?

-In the health ecosystem the impact of digital technologies is highly dependent on the availability of health data.

- Availability of health data has been a policy priority in the EU through its Digital Decade policy programme, and for the WHO which developed a **European regional digital health action plan for 2023-2030** to help countries scale up their digital transformation.

- At the national level, over 80% of EU countries have a digital health strategy with a strong priority on data access, reuse and information sharing, and now all members states have public funding available for digital health programmes.

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 **'Health'** - 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 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.

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 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.

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

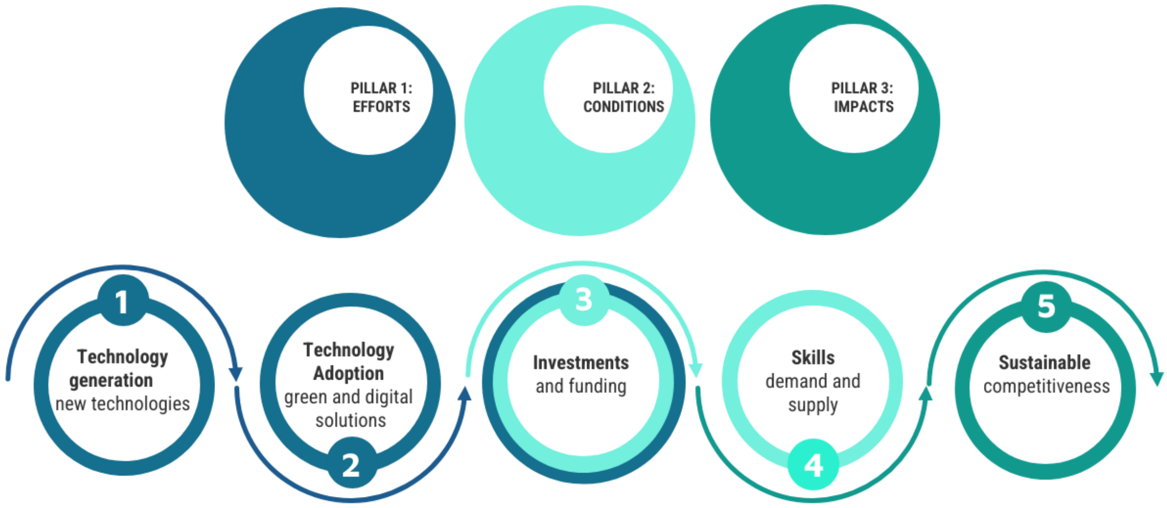
The **methodological report** that sets the conceptual basis and explains the technical details of each indicator is found in a separate document uploaded on the EMI website. Moreover, some of the specific industry codes used throughout this analysis have been also included in Appendix B. The green and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

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

[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 defence, cultural and creative culture industries, retail, proximity and social economy, and retail

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



- Technology generation
  Patent data
- Technology centres
  TC mapping

- Technology adoption
  CATI Survey
  Big Data
- Technology and new business models
  Startup data

- Private investments
  Capital investments
- Public investments
  ERDF and CORDA data

- Skills supply
  LinkedIn data
- Skills demand
  Cedefop data

- Environmental performance
  Exiobase data, Waste statistics
- Digital performance
  CATI Survey
- Industrial performance
  Prodcom and Trade

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.

This report considers and builds upon other European Commission strategies, such as the European Green Deal[4], and data sources, such as the EU's eHealth Action Plan[5] indicators. Data and information from other European and international agencies and organisations, such as the UN, the World Health Organisation (WHO), and the OECD, were also consulted.

A key input to the report has also been exchanges with stakeholders whose relevant insights are reflected in the report. Insights from the exchange with DG GROW staff were additionally used to refine especially the technology lists related to both the green and digital transition.

1.2. Scoping the ecosystem

There are vast variations among the definitions of health systems, mainly due to the different interpretation of boundaries. For the purpose of this study, we focus on the definition as outlined in the European Commission's Annual Single Market Report 2021 and 2022[6].

The health industrial ecosystem is defined as encompassing the following sectors: **Manufacturing of pharmaceuticals and their key inputs, medical devices and**

[3] Commission expert group "Industrial Forum" (2022). Blueprint for the development of transition pathways for industrial ecosystems.
[4] European commission (2019). The European Green Deal, COM/2019/640 final
[5] European Commission. eHealth Action Plan 2012-2020, COM/2012/736 final. https://health.ec.europa.eu/publications/ehealth-action-plan-2012-2020_en
[6] European Commission (2022). Annual Single Market Report, BRUSSELS, 22.2.2022, SWD(2022) 40 final

equipment and personal protective equipment; Healthcare services (medical and residential care); Health tech and related services.

Within the health ecosystem, this report distinguishes two key components:

- **Product and Service Development**: The first component focuses on the development of new products and associated services to address population health and care needs. This includes the pharmaceutical, biotechnology, and medical devices sectors, which operate within a value chain where private actors play a significant role.
- **Healthcare Delivery**: The second component encompasses entities responsible for delivering healthcare services, such as general and specialised medical practices, hospitals, and other related facilities. These services may be provided by public organisations or private entities under the close supervision of public authorities (such as state agencies or public health insurers).

The health ecosystem is a highly complex and broad network of diverse stakeholders connected through dynamic horizontal and vertical relationships along the value chain. It also relies on supportive framework conditions that ensure its efficient functioning.

The green and digital transformation of the health ecosystem must address both components, involving different actors and processes. These transformations are explored in detail in the report.

Digitalisation and green technologies are expected to reshape the health ecosystem by providing new insights and innovations. This transformation aims to deliver more effective and sustainable patient care across populations.

The health industrial ecosystem is characterised by a range of key attributes that highlight its critical role within the broader economic landscape. The health industry in the EU employs approximately 13 million people and contributes around EUR 580 bn in value added, representing about 9.5% of the EU's total GDP[7]. This positions the health sector as a vital component of the EU economy.

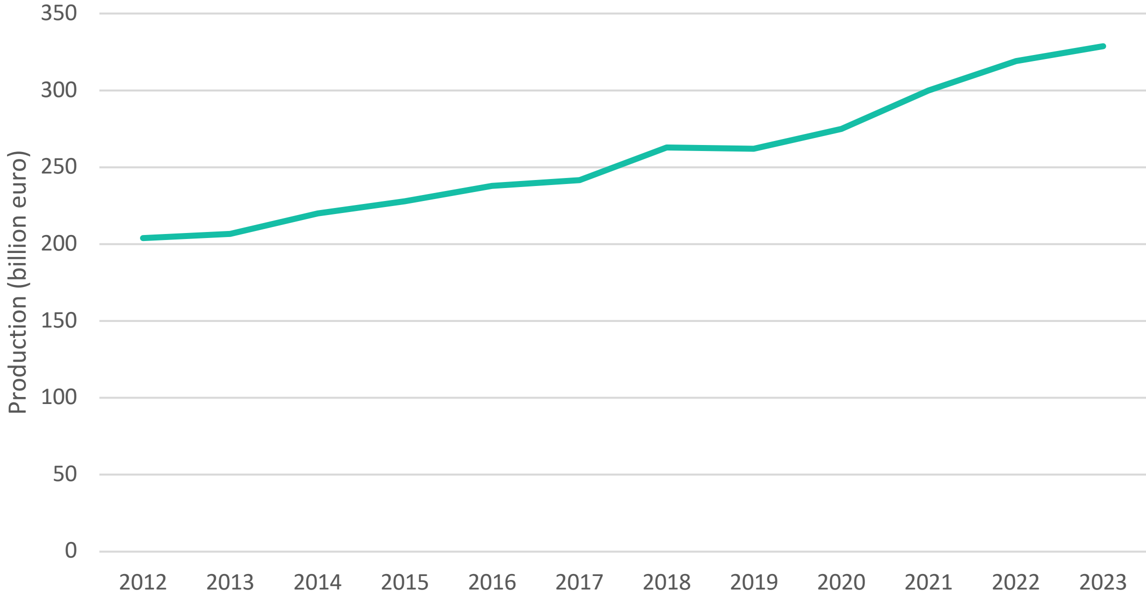
The health ecosystem comprises a diverse mix of organisations, including hospitals, clinics, pharmaceutical companies, and biotechnology firms. Notably, small and medium-sized enterprises (SMEs) play a significant role in this ecosystem; they account for approximately 99% of all health enterprises in the EU, with a substantial focus on innovation and specialised services[8].

As the population ages and healthcare needs evolve, the health sector continues to adapt, driving advancements in medical technology and patient care services, thus reinforcing its essential position in the EU's economy and society.

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

[7] EUROSTAT, Health and social work: 7,4% of all EU business in 2021. 22.03.2024
[8] European Commission European Monitor of Industrial Ecosystems. (retrieved 27.11.2024)

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



Source: IDEA Consult based on Eurostat

Figure 2 shows a **continuous growth in the production value** over the considered period of 2012-2023, highlighting the increasing importance of health sector for internal consumption and exports. The year 2018-2019 showed lower growth rates. From 2019 onwards, however, a strong resurge can be observed. This increasing trend goes hand in hand with the general boost of investments and activities related to post pandemic era in Europe.

2. Green transition

2.1. Industry efforts to green the industrial value chain

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

- **The most significant progress was achieved in the areas of material and energy conservation**, while water conservation and the adoption of circular business models continue to remain challenging.

- The most widely adopted environmental measures implemented in the health industry in 2024 included **minimising waste** (92 % of the companies), **material-saving initiatives** (82%) and **recycling efforts** (65%).

- Concrete approaches to implementing new technologies include:

- **Renewable and energy-saving technologies**: 50% of pharma and medical device companies have **adopted renewable energy technologies**. In parallel, **recycling** has been adopted by 65% and **energy-saving technologies** are already adopted by 59% of companies.
- **Advanced materials**: Recyclable and biodegradable materials are **established in the medical devices sector** (e.g. polylactic acid), which also enables to reduce health waste.
- **Biotechnology**: One-fifth of pharmaceutical and medical devices in businesses in 2024 are based on biotechnology.
- **Clean production technologies**: To minimise energy consumption and reduce CO2 emissions, **42% of businesses in the health sector have adopted clean production technologies**.
- **Waste management and recycling technologies**: Actions, taken to minimise waste include improving **tracking and managing of waste systems**, which might be soon **supported by digital technologies (AI)**. Moreover, **waste is converted into energy**.
- **Carbon capture technologies**: **Health companies** have **not adopted any carbon capture technologies, despite the health industrial ecosystem is responsible for approximately 5% of global GHG emissions**.

This section reports first on the progress of firms within the industrial ecosystem towards the green transition, focusing on the adoption of environmental technologies and circular business models. Moreover, it examines the level of investment by health companies in the green transition including green technologies, renewable energy, and circular economy solutions[9].

2.1.1. Technology generation

Technology generation is defined in terms of patenting activity based on the methodological framework. The information on green company creation in the health industrial ecosystem is not available and therefore not included in the analysis.

Patents

Patents in the context of the health ecosystem, typically involve new biological compounds, medical devices, therapeutics, or innovative health technologies. In the health industrial ecosystem, patenting is primarily driven by leading pharmaceutical companies,

[9] Chapter 2 Green Transitions was checked for spelling and wording by Fraunhofer´s AI-Chatbot FhGenie, see: https://arxiv.org/abs/2403.00039

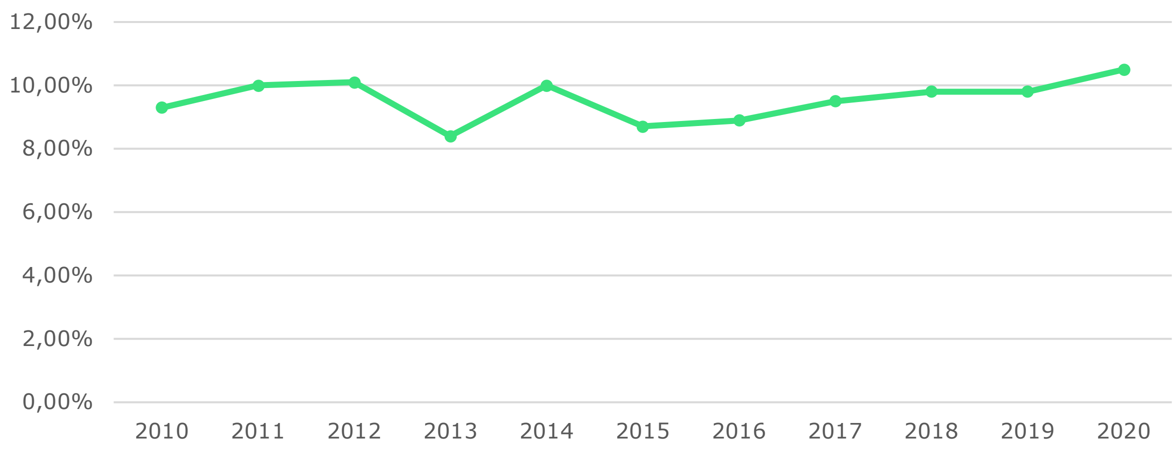
biotechnology firms, and medical device manufacturers. Additionally, academics and SMEs are playing an increasingly important role in this area.

Technology developments through patents are captured in this report for the health industrial ecosystem based on the patenting activities related to the specific sectoral activities as outlined in the NACE classification of the Annual Single Market Report 2021 and based on patent-based classifications. The analysis is based on 'transnational patents' (Frietsch/Schmoch, 2010) (i.e. PCT/WIPO filings or direct applications at the EPO, excluding double counts) and was conducted on an extended version of the EPO's Worldwide Patent Statistical Database that Fraunhofer ISI implemented locally.

Technologies relevant to ecosystems, in this case the health industrial ecosystem, are defined based on a search that refers to patent classifications (IPC) and/or use keywords to identify relevant applications across classes. Looking at the technologies related to the green transition as presented in the methodological framework, the Figure below presents the share of all green patents in all patents filed for the health industrial ecosystem among the EU27.

Steady growth has been observed since 2015, culminating in 2020, which coincides with the COVID-19 pandemic. This growth can be attributed to several factors, including the increased importance of green patents driven by the European Green Deal, as well as a relatively higher share of patenting related to the health industrial ecosystem during the pandemic. Furthermore, stronger EU policies supporting sustainability, increased funding for R&D in green health technologies, growing consumer awareness and demand for more sustainable products, and public health crises (e.g., the COVID-19 pandemic) have all contributed to the growth of green patents in the health sector, according to expert opinions.

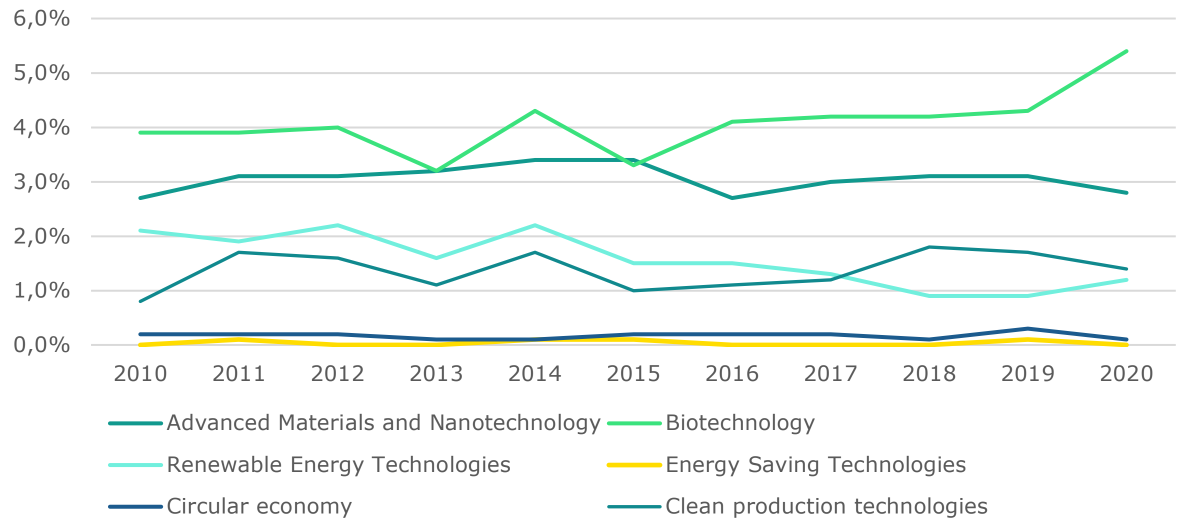
Figure 3: Share of green patents in all patents filed for the health industrial ecosystem



Source: Fraunhofer based on PATSTAT

At the level of green technologies, advanced materials, nanotechnology and biotechnology are the three leading technologies for the healthcare industrial ecosystem in terms of patenting activities (see Figure below).

Figure 4: Share of green transition technologies in overall patents filed in the healthcare industrial ecosystem



Source: Fraunhofer based on PATSTAT

2.1.2. Uptake of environmental technologies and circular business models

Green transition in the health industrial ecosystem is driven by the vital need to reduce the environmental impact of the industry by improving resource efficiency, reducing CO2 emissions, decreasing waste and recycling more efficiently (medical and pharmaceutical) waste among others.

The adoption of technologies and circular business models in the health industrial ecosystem has been explored in detail by the Eurobarometer 2024 and has been complemented by a CATI survey conducted as part of the EMI project over the period July-September 2024 (the latter focusing on pharmaceutical companies and medical device manufacturers). The sample of the survey include 96 companies in the health ecosystem.

Generally speaking, the diagnostics and medical devices sectors face unique challenges compared to pharmaceutical industry. Efforts to enhance sustainability in medical devices industry could further impact profitability for the sector.

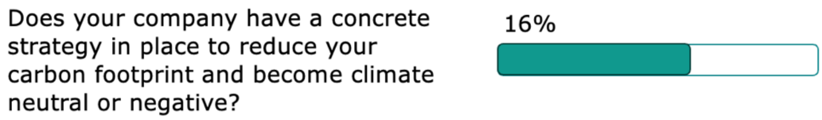
Interestingly, as some experts pointed out, smaller companies are often in the forefront of innovation within green biomanufacturing. Smaller companies can adopt new technologies more swiftly, whereas larger health companies often wait for technologies to reach a certain level of maturity before implementation, since transformation is difficult, requiring new strategies, investments, organisational changes and training or hiring new people with complementary skills. For example, a Belgian company SwiftPharma[10], which produces proteins from tobacco plants, have a process that is entirely green and circular by design, utilising entire tobacco plant and converting residues into biomass. The company finances their operations by selling ETS credits.

As the following sections will show, while the industry maintains a significant environmental impact, it has **made progress towards the green transition, particularly in the areas of material and energy conservation**. However, the **ecosystem still faces challenges in other key areas, such as water conservation and the adoption of circular business models**. These gaps indicate that while progress has been made, further efforts are necessary to fully align the industry with green transition goals.

[10] https://www.swiftpharma.eu/

According to the Eurobarometer 2024 survey results, 16% of companies have a concrete strategy to reduce carbon footprint or become climate neutral or negative, which is just 1 percentage point higher than in 2021.

Figure 5: Share of companies in the industrial ecosystem of health that has a strategy to reduce carbon footprint



Source: Eurobarometer 2024

As shown in the Figure below, **the most widely adopted environmental measure among health companies in 2024 was minimising waste**, implemented by 92% of respondents. This was followed closely by material-saving initiatives, adopted by 82% of companies, and recycling efforts, embraced by 65%. Additionally, 61% of health companies focused on energy saving within their operations. These measures highlight the industry's prioritisation of resource efficiency and waste optimisation as part of its green transition efforts.

In 2021, the priority environmental measures adopted by firms were dominated by minimising waste (61%), followed by saving energy (61%), and saving materials (50%) and water (47%. The focus on minimising waste and saving materials highlights the importance of circular thinking in the health industrial ecosystem and a shift towards this mentality. The emphasis on saving energy can also be attributed to the energy crisis and its impact on energy prices, which forced firms to prioritise these actions in order to better manage rising costs.

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

Environmental measures	***Share of adoption (2021)***	***Share of adoption (2024)***	Trend
Minimising waste	61%	92%	↑
Saving materials	50%	82%	↑
Recycling, by reusing material or waste within the company	31%	65%	↑
Saving energy	61%	61%	
Saving water	47%	50%	
Designing products that are easier to maintain, repair or reuse	45%	42%	
Switching to greener suppliers of materials	35%	31%	
Selling your residues and waste to another company	15%	28%	↑
Using predominantly renewable energy (e.g. including own production through solar panels, etc.)	27%	9%	↓

Source: Eurobarometer 2024

To improve their environmental performance, 26% of the companies surveyed indicated that they have relied on environmental services provided by third-party providers, such as energy audit, carbon footprint analysis, water audit.

In addition to implementing measures focused on enhancing resource efficiency and promoting climate neutrality, pharmaceutical and medical device manufacturers have taken a more direct approach by adopting technologies, which enable more sustainable practices. The efforts of companies within the health industrial ecosystem to advance the green transition are concentrated on several key technological areas, which aim to drive sustainability, reduce environmental impact, and enhance the overall efficiency of the ecosystem.

These technologies include among others:

- Renewable and energy-saving technologies
- Advanced materials
- Biotechnology
- Clean production technologies
- Waste management and recycling technologies
- 3D printing
- Circular business models
- Carbon capture technologies

Although the green and digital transition of the health industrial ecosystem are intertwined, this report sets out to explore the transition and technological developments independently.

Figure 7: Adoption of green technologies in percentage in the health industrial ecosystem

Green technologies	***2024***
Recycling	65%
Energy-saving technologies	59%
Renewable energy	50%
Waste management technologies	40%
Clean production technologies	39%
Advanced materials	29%
Biotechnology	20%
Additive manufacturing	13%

Source: Eurobarometer 2024

Renewable and energy saving technologies

According to the EMI enterprise survey 2024, **50% of pharma and medical device companies adopted renewable energy technologies.** In parallel**, recycling has been adopted by 65% and energy-saving technologies are already adopted by 59% of companies.** This general positive trend reflects a growing commitment to energy efficiency and renewable energy use and indicates that more businesses in the ecosystem are actively pursuing strategies to reduce energy consumption and lower their environmental impact by using more renewable energy sources.

According to consulted experts, **a growing number of biopharmaceutical and medical device companies in health sector, including several industry leaders, are making significant efforts toward sustainability in terms of energy consumption by exclusively utilising electric vehicles for their transportation needs.** This commitment not only reduces their carbon footprint but also sets a positive example for other companies in the sector. In parallel, companies in the sector are also actively working to minimise their reliance on air travel. To achieve this, they are increasingly adopting online alternatives for meetings as an example.

Advanced materials

Advanced materials are playing a pivotal role in enhancing sustainability within the health industrial ecosystem, particularly in the medical devices sector. The focus on sustainability is driving the development of different recyclable and biodegradable materials in the medical devices sector, which also enables to reduce healthcare waste[11]. For example, polylactic acid (PLA), which is a biodegradable polymer derived from renewable resources has been employed in various medical applications, such as sutures, scaffolds for tissue engineering, cardiovascular implants, dental niches, drug carriers, orthopedic interventions, cancer therapy, skin and tendon healing, and lastly medical tools/equipment, helping to the environmental impact compared to traditional plastic waste[12].

The EMI Survey 2024 revealed that close to 29% of businesses in the health sector adopted advanced materials in 2024. This growth highlights the rising importance of advanced materials in enhancing sustainability and innovation within the ecosystem.

Biotechnology

Biotechnology is a critical technology within the health sector, utilised for enhancing research and development (R&D) and innovation, as well as for promoting sustainability initiatives in the industry, more specifically red biotechnology[13] has led to the discovery and development of advanced medicines, therapies, diagnostics, and vaccines. For health particularly, it may sometimes be difficult to identify which innovations has also an impact on the green transition.

Additionally advanced diagnostic tools, such as biosensors and point-of-care testing devices, have been developed using biotechnological methods, facilitating faster and more accurate disease detection while minimising waste[14].

The EMI enterprise survey 2024 revealed that 20% of businesses in pharma and medical devices have already adopted biotechnologies in 2024, the highest among all industrial ecosystems indicating the importance of advanced technologies in enhancing sustainability and innovation within the ecosystem.

According to consulted experts, the majority of the pharmaceutical pipeline over next 10-15 years will comprise biopharmaceuticals prompting a very fast transition towards biotechnology. Thus the pharmaceutical sector relies to a lesser extend chemistry; however, there will be always certain chemical substances in use that cannot be substituted.

Clean production technologies

In the context of the health industrial ecosystem, clean production technologies play an important role in supporting the green transition across various sectors and technology fields, including medical devices and pharmaceuticals. The relevant clean production technologies in this context encompass practices that minimise industrial emissions and reduce environmental impacts across health sectors, including lower waste generation, and lower resources usage. The key areas include alternative heating technologies, air recirculation systems, advanced control systems, central production plant improvements and reduction of fuel-burning equipment as an example.

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[11] https://www.compamed-tradefair.com/en/materials/sustainable-product-design-circular-economy-in-medicine

[12] N. G. Khouri et al. (2024). Polylactic acid (PLA): Properties, synthesis, and biomedical applications – A review of the literature, Journal of Molecular Structure, 1309, 138243. https://doi.org/10.1016/j.molstruc.2024.138243

[13] European Commission (n.d.) Biotechnology. Retrieved from: https://single-market-economy.ec.europa.eu/sectors/biotechnology_en

[14] https://www.stanleyparkhigh.co.uk/revolutionizing-medical-diagnostics-biosensors-and-point-of-care-devices/

Clean production technologies in manufacturing processes can lead to lower energy consumption and reduced CO_2 emission. For instance, advanced water management systems help optimise water use and contributing to overall sustainability.

The EMI Survey 2024 revealed that 42% of businesses in the health sector have already adopted clean production technologies in 2024, indicating the rising importance of advanced technologies in enhancing sustainability and innovation within the ecosystem.

Waste management technologies and recycling

Waste is one of the most problematic impacts of the health industrial ecosystem on the environment. Therefore, **waste reduction by implementing sustainable practices such as switching from disposable instruments and equipment to reusable ones (e.g. dishes, washbowls or medicine cups for inpatient treatment, medical gowns, sterilisation trays etc.) has a high importance** to reduce harmful impacts on the environment and ultimately human health.[15]

In the biopharmaceutical sector, waste management systems integrate smart technologies for tracking and managing waste streams, enhancing both efficiency and compliance [16]. Furthermore, the implementation of environmentally friendly packaging alternatives enables to reduce single-use plastics in medical devices [17]. Also, the adoption of circular economy principles encourages the reuse and recycling of materials, especially in the medical devices industry, which can significantly reduce waste generation[18]. Also, different waste-to-energy technologies are being developed to convert waste into energy and addressing medical waste disposal challenges by producing renewable energy[19].

Furthermore, the use of digital technologies, such as AI, is significantly expected to improve waste management in the health sector by providing real-time monitoring and data analytics to optimise waste management practices [20].

The EMI enterprise survey 2024 revealed that more than 40% of businesses in pharma and medical devices adopted new waste management technologies in 2024, marking a 3% increase compared to 2023.

Some pharmaceutical companies are also trialling the return of small single use products.[21] This was the case of Novo Nordisk who launched an industry wide pilot in 2023 to return single use injection pens achieving a 25% of return after one year. The company Chiesi Ltd. has also launched an action in 2021 to take back inhalers by using pre-paid and pre-addressed envelopes available in local pharmacies, which are sent directly to a waste management company, recycling both the plastic and gas[22].

In 2023, EFPIA[23] surveyed its members on the topic of circular economy and 100% of the respondents said to be willing to collaborate in circular design and to avoid the single-use

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[15] Sustainable health systems (2022). Natural Sustainability, 5(637). https://doi.org/10.1038/s41893-022-00951-3

[16] https://indaver.com/news/single/more-storage-capacity-smart-waste-tracking-and-solutions-for-substances-of-very-high-concern

[17] https://www.cas.org/resources/cas-insights/five-ways-achieve-sustainable-medical-packaging

[18] T. Hoveling et. al (2024). Circular economy for medical devices: Barriers, opportunities and best practices from a design perspective, Resources, Conservation and Recycling, 208, 107719. https://doi.org/10.1016/j.resconrec.2024.107719

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[20] T. A. Mohan (2023). A STUDY OF APPLICATION OF AI IN CLINICAL WASTE MANAGEMENT: EXPLORING THE BENEFITS AND OPPORTUNITIES, International Journal of Civil Engineering and Technology (IJCIET), 14(2), 1-14. DOI:10.17605/OSF.IO/RE49J

[21] EFPIA (2024). White Paper on Circular Economy. https://www.efpia.eu/media/htreo44j/white-paper-on-circular-economy.pdf

[22] Murphy, Anna & Howlett, David & Gowson, Aaron & Lewis, Harriet. (2023). Understanding the feasibility and environmental effectiveness of a pilot postal inhaler recovery and recycling scheme. npj Primary Care Respiratory Medicine. 33. 5. 10.1038/s41533-023-00327-w.

[23] [8] EFPI (2024)., White Paper on Circular Economy. https://www.efpia.eu/media/htreo44j/white-paper-on-circular-economy.pdf

packaging systems. According to EFPIA, the pharmaceutical sector can adopt circularity at different levels throughout the value chain, such as product design, production process, product use, and end-of-life management.

3D printing

Additive manufacturing, widely known as 3D printing, provides innovative solutions to reduce waste and enhance sustainability in health ecosystem.

In the field of medical devices, it enables the production of complex, customised appliances with minimal material use and waste, therefore reducing the environmental damage compared to conventional manufacturing methods[24]. In addition, by creating devices tailored specifically to individual (anatomical) needs, waste associated with ill-fitting or unused products can be significantly reduced. [25]

In the biopharmaceutical sector, additive manufacturing is being used for example to develop personalised drug delivery systems. 3D-printed tablets allow for precise dosages and controlled release profiles, by reducing pharmaceutical waste and ensuring that patients receive only the necessary dosage of the medication. [26]

The EMI enterprise survey 2024 revealed that more than 14% of businesses in pharma and medical devices adopted 3D printing in 2024.

Circular business models

Circular business models in the health sector contribute to the development of a more sustainable health industrial ecosystem[27]. By producing more durable, reparable and recyclable products and devices, health sector can significantly reduce waste and extend the lifecycle of medical devices[28].

For example, leasing medical devices instead of buying allows healthcare facilities to utilise equipment without the burden of ownership, promoting maintenance and reuse[29]. This approach can reduce the costs and allows the devices to be returned for refurbishment and recycling at the end of their life cycle or lease period.

Circular business models could also include return programmes for unused medications, which help prevent environmental contamination and promote responsible disposal[30].

All these different innovative approaches are crucial for transforming the health sector into a more sustainable and resource-efficient industry. **The EMI survey 2024 revealed that more than 15% of businesses have already adopted circular business models, with an expected growth to 35%.** This rapid growth highlights the rising importance of circularity in enhancing sustainability and innovation within the health ecosystem.

For instance, medical devices such as magnetic resonance imaging devices or molecular imaging devices – should have designs that take into account reparability[31]. The rate of replacement of university hospitals or imaging centres imaging devices are every 5 to 7 years for newer models. There needs to be appropriate standards for refurbished materials.

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[24] M. Nizam et. al (2024). 3D printing in healthcare: A review on drug printing, challenges and future perspectives, MaterialstodayCommunications, 40, 110199. https://doi.org/10.1016/j.mtcomm.2024.110199

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[30] V. Suhandi, P.-S. Chen (2023). Closed-loop supply chain inventory model in the pharmaceutical industry toward a circular economy, Journal of Cleaner Production, 383, 135474. https://doi.org/10.1016/j.jclepro.2022.135474

[31] CEPS (2018). The role of business in the circular economy. https://cdn.ceps.eu/wp-content/uploads/2018/03/RoleBusinessCircularEconomyTFR.pdf

Medical devices contain high amounts of critical raw materials and rare earth elements which is in part due to the high digitalisation of these devices, needing processors, screens and memory (e.g. in MRI imaging, medical laser technologies, medical hearing aids)[32]. Phillips[33] and Siemens[34] for example exchange existing hospital equipment to upgraded new refurbished equipment at a discounted price (ibid.).

There are also new business models where instruments can be leased instead of sold, which ensures that these are returned to the manufacturer. This was the approach taken by Roche for some of their diagnostics instruments where 70% of their metals are easily recoverable[35].

As highlighted already above, a study commissioned by the European Commission has shown for the 30 countries surveyed, single use devices are prohibited from reprocessing in 17 countries, in 10 countries it is allowed and in 3 it is undecided – these leads only two manufacturers in Germany to reprocess their single use medical devices for the EU market. Health institutions' reasons for not using reprocessed devices include the limited perception of benefits, safety concerns, the lack of experience and the inability to obtain certification[36]. The potential health risks and the inability to report issues in the national surveillance systems are key concerns for adoption. Siemens reported that circular transformation would move to smaller equipment such as patient monitors and ventilators.

Carbon capture technologies

The EMI Survey 2024 revealed that until now health companies have not adopted any carbon capture technologies, but a slight growth to up to 2.5% is foreseen for the next years.

Still, the health industrial ecosystem is responsible for around 5 % of global GHG emissions. So, carbon capture technologies can play a key role in reducing global warming[37]. For example, management of emissions from hospitals and healthcare production facilities, which are substantial sources of CO2 emission[38]. can significantly reduce their carbon footprint, aligning with global sustainability goals[39]. Additionally, the pharmaceutical industry faces challenges to minimise its environmental footprint. Pharmaceutical companies are one of the most energy-intensive sectors, due to high hygiene requirements, cold-chain logistics and specific indoor conditions. The total carbon impact of the biotech and pharma industries increased more than 1% between 2021-2022. Despite these challenges, the sector has shown a strong commitment to decarbonisation over the last years, with ambitious sustainability goals driving innovation. By capturing CO2 emissions generated during the synthesis of pharmaceuticals, companies can mitigate their environmental impact and potentially utilise the captured carbon for the production of value-added products[40].

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[32] Friedrich Naumann Foundation (2022), Tackling the EU's dependency on raw materials. https://shop.freiheit.org/#!/Publikation/1355

[33] Ellen MacArthur Foundation (2021). Pioneering circularity in the healthcare industry: Royal Philips. https://www.ellenmacarthurfoundation.org/circular-examples/pioneering-circularity-in-the-healthcare-industry-royal-philips

[34] https://www.siemens-healthineers.com/magnetic-resonance-imaging/sustainability-in-mri

[35] EFPIA (2024). White Paper on Circular Economy. https://www.efpia.eu/media/htreo44j/white-paper-on-circular-economy.pdf

[36] European Commission (2024). Study on the implementation of Article 17 of Regulation (EU) 2017/745 on medical devices on the EU market. https://op.europa.eu/en/publication-detail/-/publication/35ea0c60-e82c-11ee-9ea8-01aa75ed71a1

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[39] https://www.weforum.org/stories/2022/10/cop27-how-healthcare-can-reduce-carbon-footprint/

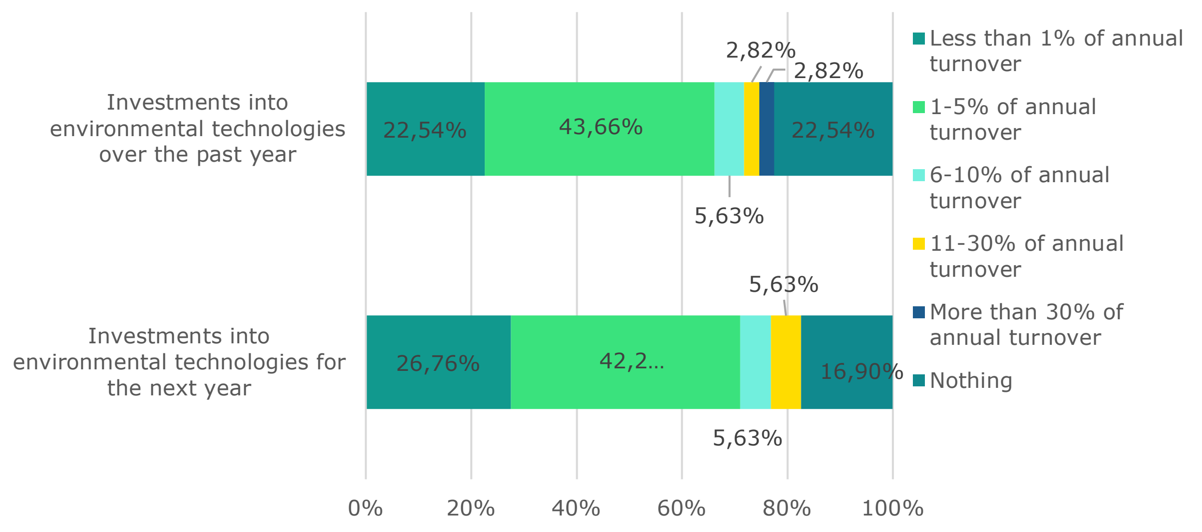
[40] https://salasobrien.com/news/decarbonization-of-pharmaceutical-manufacturing-facilities/

2.1.3. Private investments

The findings from the EMI survey in 2024 show that the majority of companies (44%) invest only between 1 and 5% of annual turnover in environmental technologies (Figure 8).The share of companies planning to allocate between 11% and 30% of their annual turnover into green technologies is expected to increased significantly, rising from 3% of current investments in 2024 to 6% in planned investments over the next years. However, it is anticipated among the survey respondents that the number of companies making larger investments above 30% of annual turnover may decrease.

The share of companies that previously invested nothing in green technologies is likely to start making investments in this area based on the EMI survey respondents. Specifically, the number of health sector companies planning to invest approximately 1% of their annual turnover in green technologies is projected to increase more than 4% (Figure 8). Meanwhile, the percentage of companies with no investments in green technologies is expected to decline from 23% to 17%. This shift reflects a growing awareness and commitment to sustainable practices among health sector companies (see Figure 8).

Figure 8: Level of investment of businesses in health into green technologies



Source: EMI Survey 2024

However, internal financial resources alone are insufficient to finance the green transformation of the health sector in Europe, making additional external private investments essential for the companies.

Overall, according to interviewed experts' opinion, there has been an increase in funding in green technologies over the course of the last ten years in Europe's health industrial ecosystem. Even though, the exact data on green investments is not available, health startups have received a total of €18 billion funding since 2010 according to the data collected by Technopolis, based on the Crunchbase database. There has been, in general, a steady increase of private equity and venture capital investment and it is equally distributed between seed-stage and late-stage funding, what points out to a higher availability of funding as well as to a growing financial interest in health startups and also interest in the consolidation and maturity of the startup landscape. Funding for green technologies is gaining increasingly attention, driven by increasing public awareness and support, combined with supportive policies on the EU level and in Member States. Additionally, various government-supported initiatives are emerging to promote the adoption of sustainable practices within the health industrial ecosystem. To meet the EU's 2030 climate target of a 55% reduction in CO_2 emissions, additional healthcare-related sustainable investments is required annually.

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

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

Public funding

- While **10.19%** of the funding for **Horizon 2020 programme project was allocated to the green transition of the health, this allocation was only 6% for Horizon Europe between 2020-2024.**

Skills

- The **development and implementation of green skills is essential for the success of the health industrial ecosystem** in adapting sustainable practices.

- The **lack of specific green skills has been identified as one of barriers to the green transition in health industrial ecosystem**. Moreover, the lack of dedicated training opportunities in sustainability further hampers the situation.

-An analysis of online job advertisements on Cedefop in 2023 revealed a particularly low share—around 2%—requiring skills related to the green transition. However, among professionals employed in the health/biopharmaceutical industry on LinkedIn, **9.91% reported possessing at least one type of green skill in 2024, significantly up from 5.58% in 2022.**

Demand for green products

- The environmental impacts of the medical sector are highlighted by the (social)media to **draw attention to the need for change**.

- Achieving a **balance between serving patients and implementing more sustainable practices remains a challenging task.**

Framework conditions that support the green transition refer to various structural and institutional elements that create an enabling environment for businesses to transition towards more sustainable and environmentally friendly practices. These conditions are crucial for driving the adoption of green technologies and fostering circular economies. Key components of these framework conditions include the generation of underlying technologies, public policy, skills demand and supply and demand-side factors among others that are analysed in the sections below.

2.2.1. Public investments

Public investments influence the attractiveness of the industrial ecosystem and promote its green transition, while also signalling a high-level commitment to sustainable development. This makes the ecosystem more attractive to businesses, investors, and other stakeholders.

EU Research and Development Framework Programmes

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

Horizon 2020 data was analysed with regard to green transition related investments within the health industrial ecosystem. 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), Horizon 2020 funded a total of 839 projects classified under healthcare. The digital and green transition related projects accounted for 47.1% **out of the total funding. In Horizon 2020 10.19% of healthcare project funding was dedicated to green transition**[41]. For Horizon Europe, considering the projects funded between 2022 and 2024, **only 6% of the funding** to health projects contributes to the green transition. These shares point towards the low importance to date of the green transition compared to digital one, which has remained close to 40% throughout of different Framework Programmes.

Several calls in Horizon Europe have targeted the green transition of the health sector under Cluster 1. Topics such as health systems and sustainable healthcare infrastructure focus mostly on projects that aim to reduce the environmental footprint of healthcare facilities, promote the use of renewable energy, and increase the circularity of medical technologies and resources. Green health technologies for sustainable diagnostics, treatments, and therapies included calls that foremost promote the development of sustainable medical devices and diagnostic tools. Lifecycle management calls aim to reduce the environmental impact of production of pharmaceuticals and medical devices, as well as strategies to minimise waste and pollution from the health industry[42].

Horizon Europe has thus far[43] provided around €700 m in funding to projects related to green transition. Among the funded projects green pharmaceuticals, environmentally friendly medical devices and circular economy have been amongst the key topics related to green transition.

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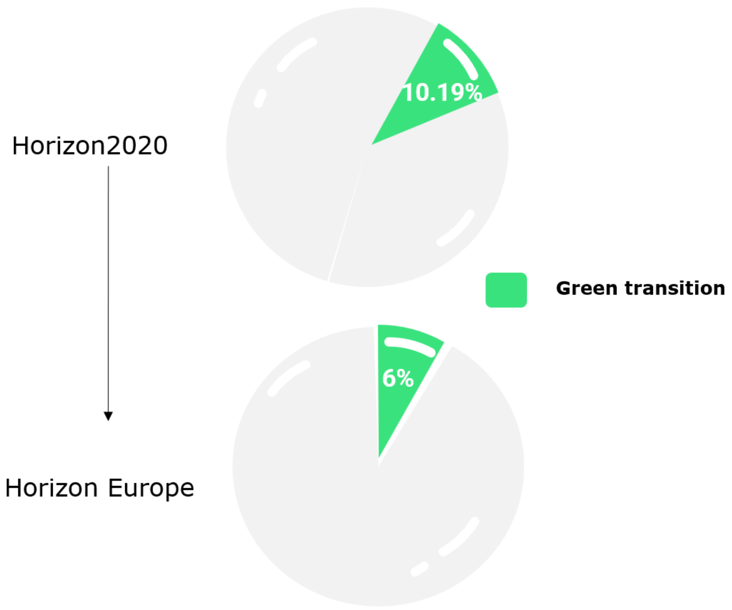
[41] The methodological report provides detailed insights into the methodology. In particular, the CORDIS data have been merged with the relevant EuroSciVoc data. EuroSciVoc connects projects to relevant scientific concepts, providing a deeper understanding of the research focus.
[42] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/home
[43] Cut-off date: March 2024

Figure 9: Total project costs spent on twin transition



Source: Technopolis Group analysis

Examples of health projects funded under Horizon 2020 and Horizon Europe supporting the green transition are described in Box 1.

Box 1: Horizon 2020 and Horizon Europe health projects supporting the green transition

CARING NATURE[44], funded through the Horizon Europe programme with an EC contribution of EUR 6 m, constructs and implements 10 healthcare specific solutions for carbon emissions and pollution (CEP) reduction demonstrated in 33 use cases. The 10 CEP-reduction solutions tackle main production sources on which HCP have exclusive control and were they act as principal actors of transition: building energy demand will be addressed through: reduction of environmental impact of construction and renovation, and utilising AI-powered energy management; reduction and valorisation of medical, food and water waste through a HCP tailored pyrolysis plant prototype and an on-site waste food digestion and drying system; reduction of patient/visitors travel through next generation telemedicine

TransPharm [45] (Transforming Pharma) is a Horizon Europe project launched in 2022 with an EC contribution of EUR 8 m. TransPharm two-track approach focusses on the one hand on the compounds itself by identifying greener and more sustainable-by-design Active Pharmaceutical Ingredients (APIs) and on the other hand reducing the environmental impact and resilience of the manufacturing process by optimising the synthesis route of new APIs in continuous flow and by proposing greener alternative solvents. The aim of the project is to (i) analyse and predict flow behaviour and environmental biodegradability of APIs and their synthesis pathways; (ii) identify greener and more sustainable alternatives to pharmaceutical products / APIs of concern; (iii) reduce the footprint and create important shortcuts in synthetic schemes of APIs; and (iv) assess the sustainability of pharmaceuticals over their entire life cycle

Source: authors based on Cordis

[44] CARING NATURE. https://caringnature.eu
[45] TransPharm. https://transforming-pharma.eu

2.2.2. Green skills demand and supply underpinning the green transition

Health industry is currently challenged to adapt their practices and technologies in response to climate change, and the need and demand for more sustainable approaches and efforts to reduce waste, emissions and pollution. As a result, the health ecosystem requires **new green skills** to ensure a sustainable health sector.

The European Green Deal (2019) has already highlighted the need for greener healthcare education and training, especially related to sustainability and more efficient management of resources. The EU's Health and Climate Change Strategy (2020) encourages the development of green skills within health sector in order to adapt sustainable practices and promotes interdisciplinary collaboration between health sector and climate scientists. The European Skills Agenda (2020) is one of the key EU policies in terms of green skills, calling for development of greener competences in health sector and training programmes to equip health sector professionals on working on more sustainable ways, such as reducing waste and promoting more sustainable practices. In 2023, the European Commission has also launched a pact for skills setting out the objectives of the skills partnership to tackle the specific challenges of the healthcare sector, where green transformation is one of the main challenges to be tackled. Then the European Commission published its Pact for skills in the large-scale partnership for the health ecosystem in 2024, which is creating a clear commitment and target, that 8% of health professionals should participate in reskilling and upskilling in sustainability annually by 2030 (representing 1.2 million of workers concerned per year).

To provide insights into the skills demand and skills supply in the health ecosystem, this study draws upon two databases, namely the Cedefop database and LinkedIn[46].

Since there is a general lack of data about specific green skill sets specific to industries, LinkedIn offers unique insights despite its limitations and diversity in usage. The LinkedIn network is the largest professional platform with a wide variety of information about their users, like profile summaries, job titles, job descriptions and fields of study. We used the platform for identification of skilled professionals in advanced technologies in the field of green transition. In order to analyse the number of professionals working in the ecosystem, we focused on occupations with a high relevance for health industrial ecosystem[47]. To harvest the data from LinkedIn, keyword capturing skills in each advanced technology category were defined and validated by industry and technology experts**.**

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. Keywords were subsequently used to construct queries for searching the database. As the health industrial ecosystem is broad, to deliver more meaningful insights we investigated the skills profiles of health professionals in **two specific sub-industries**: **pharmaceuticals and medical devices.** The analysis of the LinkedIn data provides some interesting insights about the availability of green professionals in the ecosystem in EU27 countries, as further elaborated below.

Cedefop's tool on skills intelligence provides insights into jobs and skills requested in online job advertisements by its dataset 'Skills in online job advertisement'. This dataset currently covers 27 European countries and was developed based on the collection and analysis of more than 100 million online job ads from July 2018 onwards. Skills in the Cedefop database have been analysed related to the green transition and the green pre-defined skills are from ESCO v1.1 This dataset covers 27 European countries and is based on the

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

[47] In order to extract data from LinkedIn, keywords were used to capture skills by advanced technology. The keywords used were defined in accordance with industry ecosystem standards and reviewed by technology experts. Queries have subsequently been constructed to filter the database by location and industry.

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.

2.2.2.1. Skills demand

The health industrial ecosystem is undergoing a significant transformation as new technologies and sustainability objectives are changing the way healthcare and related technologies and products are developed, produced, and used. The development and **implementation of green skills is essential for the success of the health industrial ecosystem** in this new era, as dealing with different green skills has become a daily practice.

The lack of specific green skills has been identified as one of barriers to the green transition in health and there is a lack of dedicated training opportunities on sustainability, which further hampers the situation. Against this backdrop the need to upskill, reskill and implement interdisciplinary skills related to green transition in the health sector is becoming increasingly important to cope with evolving societal expectations and needs[48].

The problem has already been acknowledged by the EU policy makers. The European Skills Agenda[49] was adopted by the European Commission back in 2020, which aims to enable businesses to develop better green skills among others and put them to use. As first step, to tackle the issue a high-level roundtable was organised for health sector stakeholders in February 2021 to discuss the requirements for upskilling and reskilling the existing workforce in the health ecosystems[50].

However, still a very low percentage of jobs in the health industrial ecosystem in the EU require green skills.[51,52]Especially important are the skills related to waste management, sustainable building designs (i.e. 0 emission buildings) and climate-resilient healthcare delivery.

This is also reflected by the Cedefop data, according to which the share of online job advertisements requiring skills related to the green transition in 2023 was only around 2%. The total number of job ads referring to green skills increased between the period from 2021 to 2022 but has been stagnating over the year from 2022 to 2023 (Figure 10).

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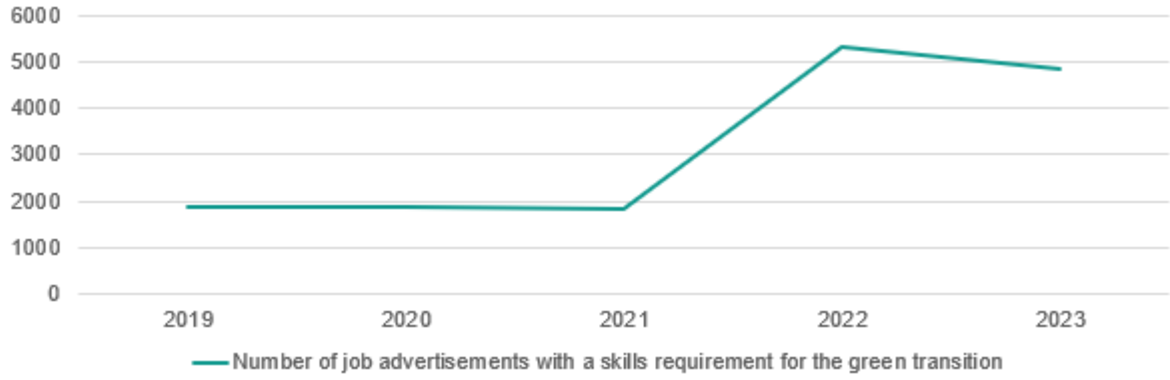
[48] European Health Parliament (2016). Digital Skills for Health Professionals, https://www.healthparliament.eu/wp-content/uploads/2017/09/Digital-skills-for-health-professionals.pdf
[49] European Commission (2021). European Skills Agenda. https://ec.europa.eu/social/main.jsp?catId=1223
[50] Idem.
[51] European Commission (2017). The digital skills gap in Europe. https://digital-strategy.ec.europa.eu/en/library/digital-skills-gap-Europe
[52] President of the EU Commission, Ursula von der Leyen's 2022 state of the union address came with the announcement that 2023 will be the European Year of Skills. The Commission has also made one of its priorities "A Europe fit for the digital age" and a digital transition that benefits everyone, setting a target for basic digital skills at a minimum of 80% of EU citizens.

Figure 10: Share of online job advertisements with a requirement for environmental skills in health



Source: Technopolis Group based on Cedefop

Specific to the health industrial ecosystem[53], **there were 1 638 538 unique job advertisements from companies in 2023 in the EU.** The total number of green and digital online job advertisements within health in EU27 countries amounts to 517 729 in the year 2023, which represents 31.6% of total online job advertisements in 2023. Out of these, **only 2% of the job ads included a requirement for environmental skills**. The equivalent data for 2024 is not available.

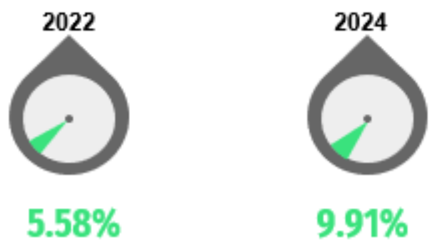
The main green skills that appeared most often on health-related online job advertisements are knowledge about biology in environmental context and also environmental regulation and legislation, which are especially important for companies in navigating the rapidly changing regulatory environment related to sustainability and circularity according to consulted experts.

2.2.2.2. Skills supply

To gain insights into the supply of skilled professionals, the **LinkedIn database** has been consulted. LinkedIn is the largest professional network platform with rich information like profile summary, job title, job description and field of study, which can be used for the identification of skilled professionals with skills relevant to the green transition. In particular, green skills have been identified as skills related to biotechnology, renewable energy technologies, circular business models, and clean production technologies.

Within the registered professionals on LinkedIn employed in the health/biopharmaceutical industry, **9.91% indicated to have one type of green skill in 2024**, which is significantly higher than in 2022 when only 5.58% were found to have at least one green skill. Similar data on the medical devices sector is not available.

Figure 11: Share of professionals in the pharmaceutical industry with green transition skills



Source: Technopolis Group based on LinkedIn

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

The LinkedIn data in 2023[54] also indicated that green professionals are mostly employed in the sphere of energy management (i.e. especially in massive productions facilities of pharmaceuticals but also medical devices) and recycling. Recycling is especially urgent topic in medical device manufacturing, to produce devices in a sustainable way, which explains why this sub-category has a higher green focus compared to the others[55].

2.2.3. Demand for green products

This section examines the demand among European citizens for greener and more sustainable health products, such as medical devices, biopharmaceuticals well as their acceptance of these innovative products.

As sustainability has been a growing priority of the EU in the last decade, the health sector, including the medical devices and biopharmaceuticals sector, must comply with European legislation in this field and users (i.e., the public) are important stakeholders in this transition toward environmentally sustainable healthcare.

The development of new delivery systems, new products that pose a lower environmental risk, waste recycling, the reduction of water usage, greener manufacturing methods, and recyclable packaging have intensified attention on this topic[56]. According to MedTech Europe, European consumers increasingly believe that the health sector should implement more sustainable practices to reduce waste and CO2 emission. Furthermore, the images of the environmental impacts of the medical sector are used by the (social)media to draw attention to the need for change, and there is no lack of claims from non-profit organisations for a shift towards sustainable management of medical sector and especially pharmaceutical companies[57].

However, the health industrial ecosystem faces a challenge as no other sector, as the health and safety of human lives are at stake. An important task to succeed from a health sector perspective, is to find the balance between serving patients on the one hand and implementing more sustainable practices on the other.

Consumers are demanding responsible and environmentally friendly products, and the health sector has contributed to meeting this demand and to improving public perception of the industry by giving greater consideration to environmental issues and sustainability[58].

Current trends in green and public procurement within the health sector also emphasise the importance of adopting sustainable practices. These guidelines aim to encourage healthcare organisations to prioritise products that have a reduced environmental impact. It becomes essential to consider not only the immediate costs associated with purchasing medical equipment but also the long-term implications and environmental footprint. For example, Siemens has developed energy-saving solutions specifically designed for their MRI equipment[59].These innovations not only enhance the efficiency of these machines but also significantly reduce operational costs over time.

Also, the consulted experts believed that sustainability will be a strategic priority over next 10 years (e.g. reusable medical devices and circular business models in general), which is strongly influenced by increasing consumer demand for more sustainable options and alternatives to current products and services.

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[54] European Commission (2023). Monitoring the twin transition of industrial ecosystems.
[55] European Commission (2023). Monitoring the twin transition of industrial ecosystems.
[56] M. Milanesi et. al (2020). Pharmaceutical industry riding the wave of sustainability: Review and opportunities for future research. *J. Clean. Prod., 261*, 121204. https://doi.org/10.1016/j.jclepro.2020.121204
[57] M. Milanesi et. al (2020). Pharmaceutical industry riding the wave of sustainability: Review and opportunities for future research. *J. Clean. Prod., 261*, 121204. https://doi.org/10.1016/j.jclepro.2020.121204
[58] M. Milanesi et. al (2020). Pharmaceutical industry riding the wave of sustainability: Review and opportunities for future research. *J. Clean. Prod., 261*, 121204. https://doi.org/10.1016/j.jclepro.2020.121204
[59] European Commission Joint Research Centre (2022). Assessment of the European Union Green Public Procurement criteria for four product groups. https://publications.jrc.ec.europa.eu/repository/handle/JRC127215
https://www.siemens-healthineers.com/magnetic-resonance-imaging/sustainability-in-mri

2.3. The impact of the industrial ecosystem on the environment

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

- The **health industrial ecosystem keeps on facing** significant environmental challenges. In particular, the sector **still lags behind in addressing its impact on water usage and waste reduction.**

- In 2020, **the contribution of health ecosystems to greenhouse gas (GHG) emissions was 4.6%**, corresponding to 27.6 megatons, which is an increase from **3.7% in the previous year.**

- Some **EU countries are participating in global initiatives to develop a clear understanding of GHG emissions within their health industries and to formulate specific plans for more sustainable practices in the health industrial ecosystem**.

- The demand for **water, which is a key input for health-related industries, remains particularly high, with consumption levels between 26 and 28 Mm3 since 2020.** Its recovery and recycling require further enhanced management strategies.

This section focuses on selected impact areas relevant to the health industrial ecosystem, examining its environmental impact and performance[60]. It provides long-term trends across various indicators, including overall emissions, energy consumption, resource degradation, biodiversity loss, and water scarcity. The analysis primarily relies on secondary data sources. Furthermore, it reports on indicators developed through the Exiobase[61] dataset. This dataset allows to measure the environmental impact of industrial ecosystems via the environmental impact of both production and consumption.

The following sections will illustrate that **while the health industrial ecosystem has made progress in reducing its emissions footprint, it continues to face significant challenges in other environmental areas**. In particular, the sector still lags behind in its impact on water usage and waste reduction. These issues highlight the need for further improvements in the health sector. However, in parallel, it is important to recognise that **the most effective way of reducing the emissions and improve sustainability of the health sector is reducing the need or *demand* for healthcare services among public in the first place**[62]. Prevention, which primarily involves changing individual and societal attitudes to support more environmentally sustainable care consumption, is one approach to reducing the demand for healthcare and associated greenhouse gas (GHG) emissions while improving population health. To minimise the negative impact of the health sector on climate change and sustainability, it is essential to address both the demand for health services and their supply.[63]

GHG emissions of health industrial ecosystems

Within the ambitious plan of the EU to reduce its net greenhouse gas (GHG) emission by 55% by 2030 and then in a second step to 90% by 2040 compared to 1990, and to achieve neutrality by 2050[64], the health industrial ecosystem has a great scope to tackle emissions

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[60] Green transition section of the report was checked for spelling and style by Fraunhofer´s AI-Chatbot FhGenie, see: https://arxiv.org/abs/2403.00039
[61] About Exiobase. Retrieved from: https://www.exiobase.eu/index.php/about-exiobase
[62] Z. Or and A-.V. Seppänen (2022). The role of the health sector in tackling climate change: A narrative review, Health Policy, 143, 105053. https://doi.org/10.1016/j.healthpol.2024.105053
[63] Z. Or and A-.V. Seppänen (2024). The role of the health sector in tackling climate change: A narrative review, Health Policy, 143, 105053. https://doi.org/10.1016/j.healthpol.2024.105053
[64] European Commission (2024). Securing our future Europe's 2040 climate target and path to climate neutrality by 2050 building a sustainable, just and prosperous society, COM/2024/63 final.

from its own sector. The European Union recognises the impact of the environment on human health in the Proposal for the 8th Environment Action Programme to 2030[65]. The European Environment Agency (EEA) warned that the European continent is the fastest warming continent, which will have consequences on health due to heat stress, increased transmission of infectious diseases altogether putting high pressure on the health industrial ecosystem[66].

Health ecosystems have been shown to be a major contributor to GHG emission, which represented 4.6% of global GHG emissions in 2020, though absolute GHG emissions decreased from 2019 by 3.7%[67]. The European Union is the third top emitter with 12% of global GHG emissions behind the United States and China (with 27% and 17% of emissions respectively)[68]. In the health sector, emissions are computed looking at emissions linked directly to the running of healthcare facilities (in hospitals or healthcare professionals' practices), as well as the indirect emissions of goods and services used by them[69]. This includes health related industries such as the production of medical devices and equipment, production of pharmaceuticals, but also other emissions such as treatment of waste, transport of employees and patients, electricity distribution, food and catering or construction emissions[70]. As illustrated in the Figure below, GHG emissions from the health ecosystem peaked in 2020 and remained at elevated levels in the following period. Health ecosystems can reduce their emissions by transitioning to zero-emission buildings and infrastructure, adopting renewable electricity, implementing circular and sustainable healthcare waste management, improving the efficiency of health systems, producing low-carbon pharmaceuticals, promoting sustainable travel and transport, and introducing sustainably grown food in their facilities (listed in order of importance in terms of GHG emission reduction)[71].

GHG emissions in the health industrial ecosystems can be tackled under the broader objectives of the European Green Deal[72] that propose a number of measures applied across ecosystems. This includes transitioning to a cleaner energy system, with a goal of increasing the share of renewable energy in the European energy mix to 40% by 2030 and reducing energy consumption by 36%. It also involves renovating buildings, including public facilities, to improve energy efficiency and promoting greener transportation, aiming to reduce car emissions by 55% by 2030.

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[65] Decision (EU) 2022/591 of the European Parliament and of the Council of 6 April 2022 on a General Union Environment Action Programme to 2030 (2022), PE/83/2021/REV/1.

[66] European Environment Agency (2024). European Climate Risk Assessment (EUCRA) Luxembourg: Publications Office of the European Union.

[67] M. Romanello et al. (2023). The 2023 report of the Lancet Countdown on health and climate change: the imperative for a health-centred response in a world facing irreversible harms, The Lancet Countdown, 402, 2346–2394.

[68] Health Care Without Harm (HCWH) and ARUP (2021). Global Road Map for Health Care Decarbonization: A navigational tool for achieving wero emissions with climate resilience and health equity, Annex C., 2.

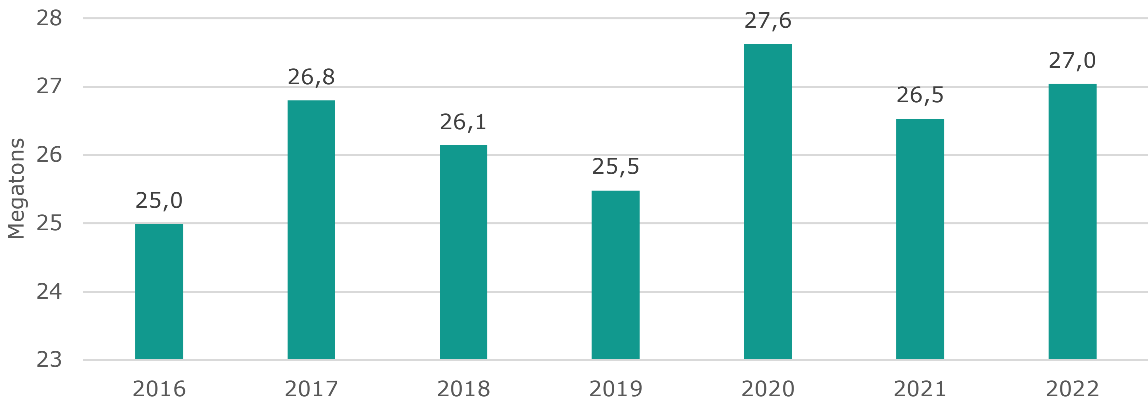
[69] Health Care Without Harm (HCWH) and ARUP (2022). Designing a net zero roadmap for healthcare. Technical Methodology and Guidance.

[70] Health Care Without Harm (HCWH) and ARUP (2022). Designing a net zero roadmap for healthcare. Technical Methodology and Guidance.

[71] Health Care Without Harm (HCWH) and ARUP (2021). Global Road Map for Health Care Decarbonization: A navigational tool for achieving wero emissions with climate resilience and health equity, Annex C., 2.

[72] European commission (2019). The European Green Deal, COM/2019/640 final.

Figure 12: Greenhouse gas emissions in the health ecosystem (consumption and production accounts)



Source: Technopolis Group based on Exiobase

Waste

Other aspects linked to emissions require more specific solutions, such as healthcare waste management and the production of pharmaceuticals.

Healthcare waste is a wide area of discussion, where some aspects are difficult to assess. For instance, data on the use of anaesthetic gases and metered dose inhalers are not included in the World Input Output Database used for assessing carbon footprint of an industry, but it has been estimated that their uses at least represent 0.9% of the global health sector footprint. These products use gases that have much higher warming potential than carbon dioxide[73], where 95% of their emissions occur in the waste phase[74]. The solution may lie in using alternative products (ibid).

The volume of plastic waste emanating from healthcare use is not known but has been estimated to represent 30% of all healthcare waste[75]. Healthcare facilities should therefore think about how they can reduce, recycle and reuse products, bearing in mind that re-used supply should not bear unacceptable health risk to patients[76].

The disposal of pharmaceutical products is also a cause of environmental concern and active ingredients can then be found in the environment and having a potential adverse effect on health and on natural ecosystems[77]. This may be caused by emissions from manufacturing plants, or intensive agriculture and aquaculture (ibid.) but also to some extent by the improper disposal of medication (including expired medication) of households[78]. Indeed, medicines disposed via sinks and toilets can risk leaking into freshwater systems which are not designed to deal with such waste, as those disposed in municipal solid waste can also enter the environment (ibid.). Medication is designed to interact with living organisms and have an impact on animals' physiology and behaviour creating also risk to human health. For example, the improper disposal of antibiotics can amplify the risk of antibiotic resistance. Furthermore, population aging, along with other changes, is likely to increase the use of medicines across OECD countries, further exacerbating this issue.

The impact of GHG emissions and pollution on health

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[73] Health Care Without Harm (HCWH) and ARUP (2021). Global Road Map for Health Care Decarbonization: A navigational tool for achieving wero emissions with climate resilience and health equity, Annex C., 2.

[74] S. Andersen et al. (2023). Assessing the potential climate impact of anaesthetic gases, The Lancet Planetary Health, 7, 7, 622-629.

[75] C. Rizan et al. (2020). Plastics in healthcare: time for a re-evaluation, Journal of the Royal Society of Medicine, 113, 2. https://doi.org/10.1177/0141076819890554

[76] World Health Organization (2014). Safe management of wastes from health-care activities, 2.

[77] OECD Studies on Water (2019). Pharmaceutical Residues in Freshwater, OECD.

[78] OECD (2022). Management of Pharmaceutical Household Waste: Limiting Environmental Impacts of Unused or Expired Medicine, OECD.

Overall, climate change has a growing impact on health resulting from severe weather, extreme heat, air pollution, availability of drinkable water and food supply[79]. Indeed, there are high risks across different ecosystems and the European Climate Risk Assessment report[80] details the cascading impacts of climate related hazards and non-climatic risks drivers to health. The report shows that risk to health include heat stress, respiratory diseases, cardiovascular diseases, strokes, worsening of chronic conditions, increase of vector borne, food borne, water borne diseases as well as mental health related problems. These are due to heatwave, general warming, wildfire, ocean warming, floods and droughts and could be combined with aggravated factors such as increased urbanisation and lower green cover, and longer and more intense pollen seasons (ibid and the Lancet Countdown report[81]). It is important to note that age, biological factors (e.g. pregnancy) and other pre-existing health conditions (chronic illnesses, mental illnesses, or other non-communicable diseases) and social factors (poverty exclusion of access to healthcare, or discrimination) can increase risk factors towards health outcomes due to climate change.

Policies to tackle climate change in the health industrial ecosystem in the EU

Policies tackling GHG emissions and broader actions that EU countries are undertaking are rarely designed specifically for health industrial ecosystems. In order to best support policy to prepare and adapt to the impact of climate change on health, the EU is relying on the European Climate and Health Observatory[82]. The observatory monitors key climate related risks, health policies and provide evidence-based solutions for public health and health care interventions.

A few EU countries are taking part in global initiatives to (1) build a clear understanding of GHG emissions within their health industries and (2) build specific plans for more sustainable health, to reach eventually a zero-carbon system. The COP26 in 2021 has enabled to form the ATACH[83] network, made of nations committing to the two above issues (including 8 EU countries: Austria, Belgium, France, Germany, Ireland, Netherlands, Poland, Spain). A second noteworthy initiative is the net zero roadmap[84] lead by Health Care Without Harm Europe, where 3 EU countries (i.e. Belgium, Ireland, Portugal) are working on similar objectives. The growing commitment of countries is further shown by the first health Day at the COP28[85], and the adoption of the COP28 Declaration on Climate and Health[86] which was signed by all EU27 countries. The European Commission through its EU4Health programme is also funding area of actions linked to crisis preparedness and to prevent and tackle risks brought by environmental, climate and chemical threats[87].

Resource utilisation

Indicators for the resource utilisation feature materials extraction (fibres, synthetics, petrol, etc.), land use (km2) and water consumption (Mm3), respectively. The **health industrial ecosystem is a significant contributor to global resource consumption in terms of raw materials[88]**. The Exiobase indicators on **ecosystem damage** as a result of the health industrial ecosystem indicate that, over the past years, the ecosystem

[79] Health Care Without Harm (HCWH) and ARUP (2019). HEALTH CARE'S CLIMATE FOOTPRINT, Climate-smart health care series, 1. and M. Romanello et al. (2023). The 2023 report of the Lancet Countdown on health and climate change: the imperative for a health-centred response in a world facing irreversible harms, The Lancet Countdown, 402, 2346–2394.

[80] European Environment Agency (2024). European Climate Risk Assessment (EUCRA) Luxembourg: Publications Office of the European Union.

[81] M. Romanello et al. (2023). The 2023 report of the Lancet Countdown on health and climate change: the imperative for a health-centred response in a world facing irreversible harms, The Lancet Countdown, 402, 2346–2394.

[82] European Climate and Health Observatory

[83] https://www.atachcommunity.com/the-challenge/

[84] https://europe.noharm.org/climate-smart-healthcare/operation-zero

[85] https://www.who.int/news-room/events/detail/2023/12/03/default-calendar/cop28-health-day

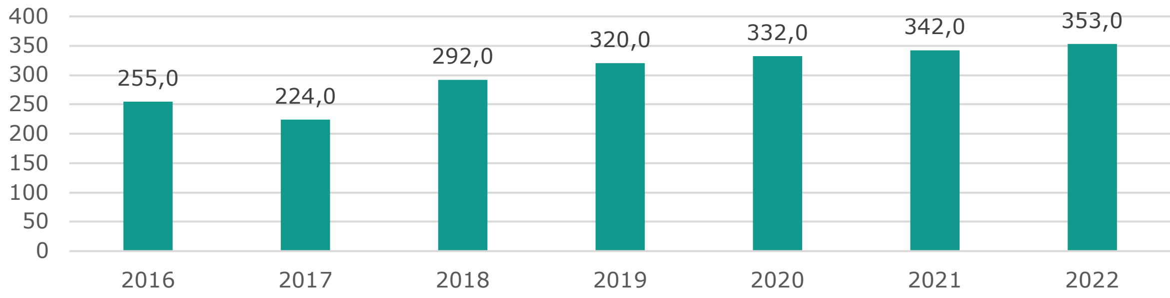
[86] COP28 UAE (2024). COP28 Declaration on Climate and Health.

[87] European Commission, 2022, SUMMARY: EU4Health - 2023 work programme.

[88] K. Ostertag et al. (2021). Sustainable resource use in the health care sector – exploiting synergies between the policy fields of resources conservation and health care.

damage has been moderately increasing. One of the driving reasons behind it is most likely the steady intensification of the overall EU production since 2018[89].

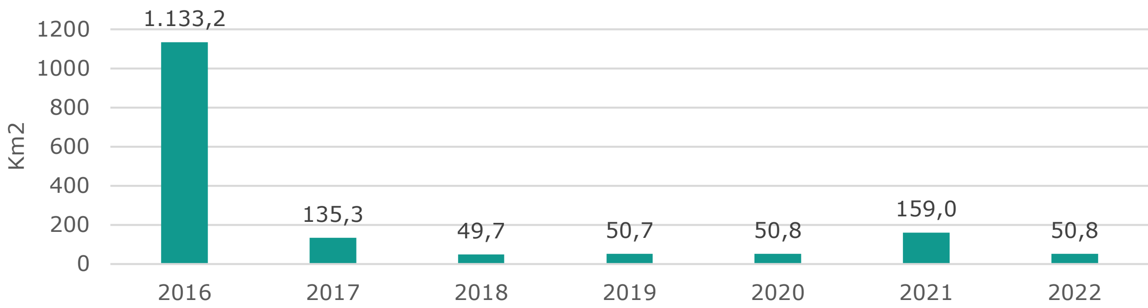
Figure 13: Health industrial ecosystem damage in the EU27



Source: Technopolis Group based on Exiobase

The use of land by the health sector plays a minor role and is substantially lower than that of other ecosystems. Trends have remained stable since 2017, with a peak in 2021 (see Figure below).

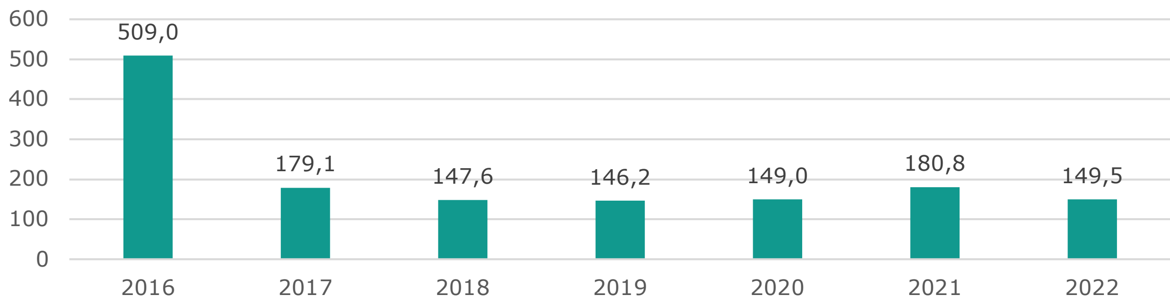
Figure 14: Land use of the health industrial ecosystem in the EU27



Source: Technopolis Group based on Exiobase

Regarding raw materials extraction, the industries' demand is particularly high for different metals and plastic. The second highest driver is manufacturing of medical and surgical equipment and orthopaedic appliances. The Exiobase indicators provide insights into the amounts of used and unused materials (**material extraction**) for the consumption and production related to the health industrial ecosystem. The trends in both consumption and production within the EU exhibit fluctuations, yet overall, they tend to stabilise around consistent levels since 2017 (see Figure below).

Figure 15: Material extraction of the health industrial ecosystem in the EU27

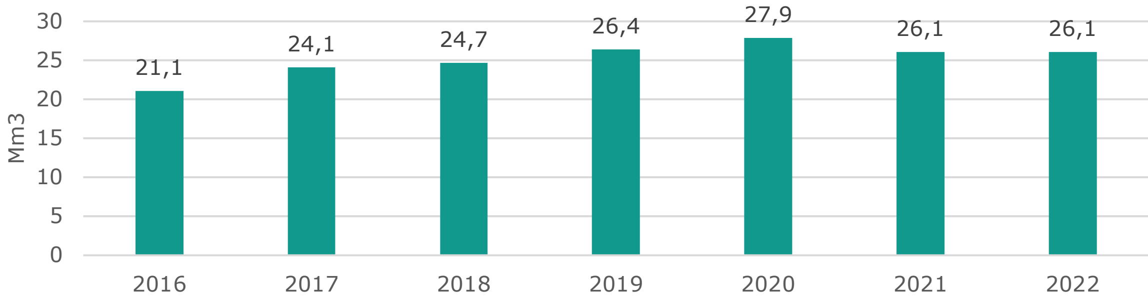


Source: Technopolis Group based on Exiobase

[89] World Health Organization (WHO). (2020). The environmental impact of the health sector: A global review. World Health Organization.

In addition, Exiobase indicators provide more insights into resource utilisation and the implications thereof. For instance, water is a key input for health-related industries.

Figure 16: Blue Water use of the health industrial ecosystem in EU27



Source: Technopolis Group based on Exiobase

The total water consumption of the health industrial ecosystem is generally stable since 2019, ranging between 26 and 28 Mm3 since 2020, with a slight peak in 2020, both when considering consumption and production in the EU. Reducing and recycling water consumption is an increasingly important strategic goal of the pharmaceutical industry. The health industry in general is extremely water intensive. The production processes are designed to be resilient and ensure patient safety and thus require extensive cleaning processes. However, due to sustainability goals and potential global drought, companies are actively rethinking their water management strategies[90].

[90] https://www.niras.com/projects/cutting-down-water-consumption-in-the-pharmaceutical-industry/

3. Digital transition

3.1. Industrial efforts into the digital transition

What is the progress of industrial efforts towards digitalisation?

- There has been **a significant increase in the adoption of AI, IoT and Cloud technology in 2024**. Over half of businesses have reported the use of Cloud computing, and around a third of companies are reporting the use of AI and IoT.

- The largest level of **investment in advanced digital technologies is focused on big data, robotics, cloud computing and edge computing** where over 75% of companies reported an investment between 1% and 10% of their annual turnover.

- **The European Health Data space** serves as an important resource, as the sector has a problem with fragmentation of data.

- Among the technology centres active in the health ecosystem and in digital technologies, the majority are engaged in advanced manufacturing and robotics, micro- and nano-electronics (MNE) and photonics, as well as AI and big data.

- Since 2019, there is a slowdown of creation of digital health startup companies.

- Looking into the type of advanced digital technologies used by startups in the health industrial ecosystem, **a majority of new startups use AI.**

3.1.1. Technology generation

Technology generation captured by patents for the digital transition in the health industrial ecosystem represent a complementary picture to those patenting activities presented under the green transition section above.

The analysis of the share of patents related to digital technologies compared to all patents filed by companies in the health industrial ecosystem from 2010 to 2020 is shown in the Figure below. This analysis shows that **from 2010 to 2016 there is an upward trend in terms of the share of digital patent applications for companies in the health industrial ecosystem from a little above 5.2% to over 8%. Between 2016 and 2019, the share of digital patent has remained stable at around 8.5%.**

When comparing the health industrial ecosystem innovative activities in terms of patenting with other industrial ecosystem, it is important to note the important role that intellectual property plays in the ecosystem[91]. Indeed, the EPO reports a slowdown in patenting activities in 2020, where medical technologies, pharmaceuticals and biotechnologies are shown to be on a strong upward trend in 2020. While the report notes that patenting overall increases in digital health technologies, it is important to note that China is by far the country submitting the most patent applications in the area followed by the US, and the most important domains of application include radiology, oncology, and ophthalmology[92].

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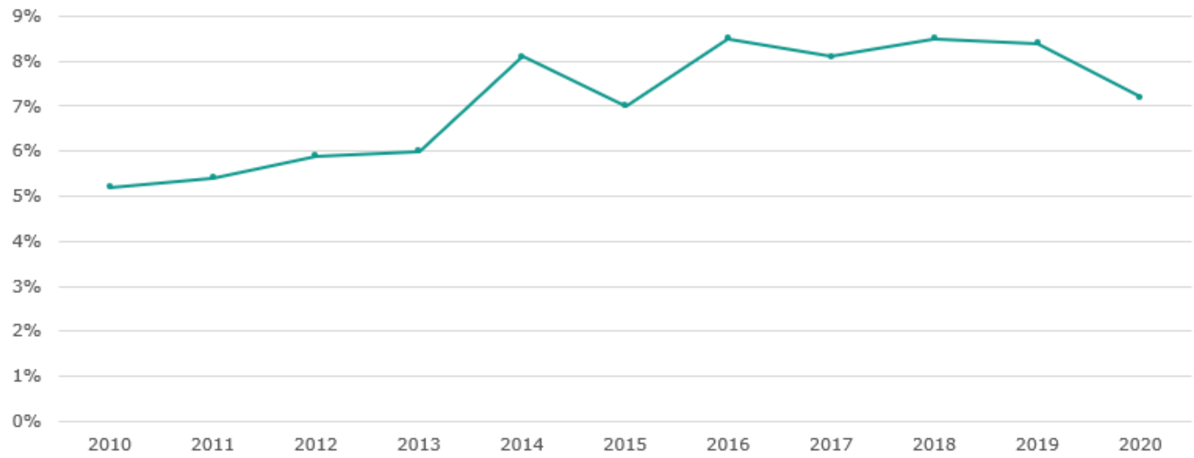
[91] EPO (2021). Healthcare innovation main driver of European patent applications in 2020. https://www.epo.org/en/news-events/news/healthcare-innovation-main-driver-european-patent-applications-2020

[92] Benjamens et al. (2023) Forecasting Artificial Intelligence Trends in Health Care: Systematic International Patent Analysis. JMIR AI. https://ai.jmir.org/2023/1/e47283; Insights by Greyb (2024). Digital Health & AI – Patent Innovation & Trends. https://insights.greyb.com/digital-health-ai-patent-innovation/; Gu et al. (2024). Evolution of Digital Health and Exploration of Patented Technologies (2017-2021): Bibliometric Analysis. https://www.i-jmr.org/2024/1/e48259

Figure 17: Share of digital patents in all patents filed for the health industrial ecosystem in EU27

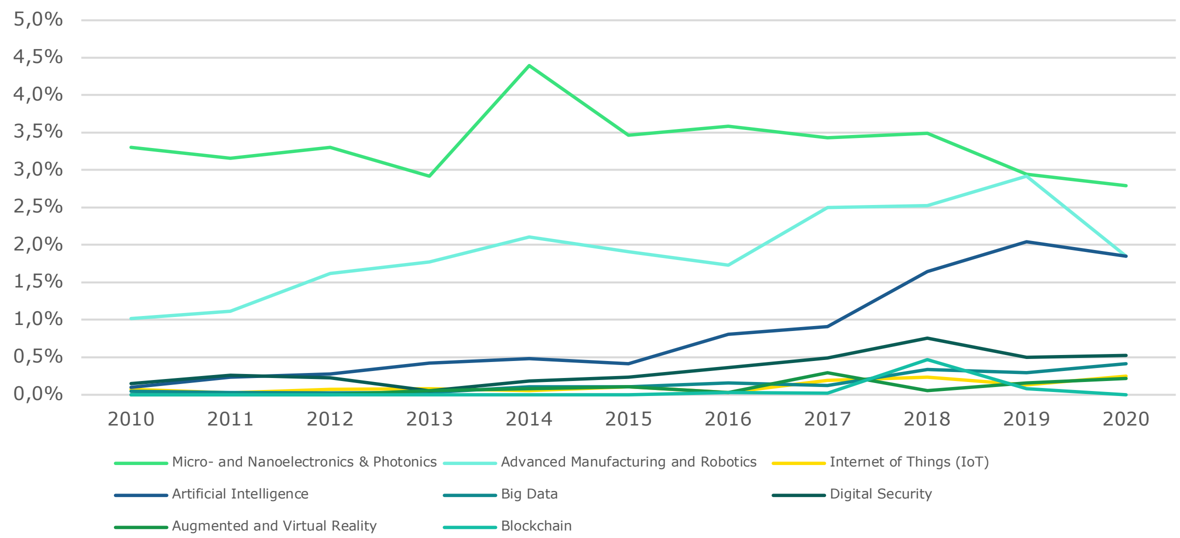


Source: Fraunhofer based on PATSTAT

Micro- and nanoelectronics, photonics, as well as advanced manufacturing technologies and robotics, are the two leading technology groups in the health industrial ecosystem in terms of patenting activities from 2010 to 2020 (see Figure below), significantly outpacing all other technologies.

Recent years have shown **a continuing increase in patenting activities for advanced manufacturing and robotics, while micro- and nanoelectronics & photonics saw a decline,** from 3.5% in 2019 to 1.9% in the pandemic year of 2020.

Figure 18: Share of respective digital transition technologies in overall patents filed in the healthcare industrial ecosystem



Source: Fraunhofer based on PATSTAT

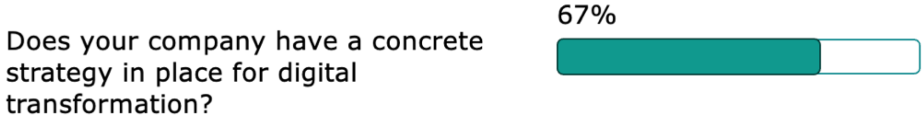
3.1.2. The uptake of digital technologies in the health industrial ecosystem

This section discusses the uptake of digital technologies in the health industrial ecosystem. The analysis in this section distinguishes between two levels, **broader digitalisation** processes as well as the development and adoption of **advanced digital technologies** by companies. This section analyses the uptake of digital technologies in the EU based on survey results and Eurostat statistics.

It has to be noted that the survey results encompass only the pharmaceutical and the medical devices industry and no hospitals or healthcare service providers were interviewed.

The digital transformation in broader terms is well under way in the health industrial ecosystem. Indeed, the EMI Enterprise survey 2024 reveals that almost three quarters of companies in the health industrial ecosystem have a concrete strategy for their digital transformation. The companies were asked whether they have a concrete strategy in place for digital transformation.

Figure 19: Share of companies in the health industrial ecosystem (pharma and medical devices) that adopted a strategy for the digital transformation



Source: EMI Enterprise Survey 2024

The digitalisation of the health industrial ecosystem is a pre-requisite to the use of advanced digital technologies that can be conducive to product innovations.

Overall trend in advanced digital technologies

In terms of advanced digital technologies, the health industrial ecosystem is making good progress towards the target set by the European Commission in line with the Europe's Digital Decade targets for 2030. This policy document specifically targets an up-take of use of big data, AI or cloud computing[93], which are the technologies that have the widest applications across the health industrial ecosystem. Other advanced digital technologies include the Internet of Things (IoT), augmented and virtual reality, micro and nanoelectronics and photonics, blockchain, or digital twins.

The Figure below shows the share of businesses in pharmaceuticals and medical devices that have adopted different advanced digital technologies, based on the EMI enterprise survey data collected in 2024. Cloud computing is the most widely adopted digital technology, with over half of the respondents reporting its use.

There has been an increase in the adoption of Cloud, AI and IoT in 2024. Over half of businesses have reported the use of Cloud computing, and **just under a third of companies reporting the use of AI and IoT.** Additionally, there has been progress in the adoption of big data technologies among health companies. This indicates a positive trend for companies in the health industrial ecosystem in adopting key advanced digital technologies, as outlined in the Digital Decade policy programme targets. In addition to the key technologies discussed in the Digital Decade policy programme targets, it is worth noting that around a fifth of the companies surveyed also report adopting robotics in their activities.

[93] European Commission, Europe's Digital Decade: digital targets for 2030. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en

Figure 20: Share of businesses in health indicating the use of digital technologies (pharma and medical devices)

Digital Technologies	***Share of adoption (2023)***	***Share of adoption (2024)***
Cloud	**31%**	**53%**
Internet of Things	**20%**	**31%**
Artificial Intelligence	**14%**	**29%**
Big Data	**15%**	**18%**
Augmented and Virtual Reality	7%	2%
Robotics	17%	18%
Blockchain	3%	8%
Edge Computing	0%	4%

Source: EMI Enterprise Survey 2024

The rate of adoption of these technologies highlights that some advanced digital technologies have a different level of impact. For instance, the use of AI together with big data and cloud technologies have a wide variety of applications in the health industrial ecosystem (as elaborated below). The other advanced technologies have also many applications in the ecosystem but are narrower in scope. An overview of the potential impact of the technologies are discussed below, together with an indication of their adoption, based on information gathered in the EMI Survey in 2024.

Artificial Intelligence: Adoption and impact on industrial competitiveness

Artificial Intelligence entails the capabilities of machines to generate knowledge or learn from patterns in the data and in turn being able to identify complex patterns in the data and make predictions[94]. **AI has a wide range of applications in the health industrial ecosystem, from improving the process of developing new drugs, to improving diagnostics, process data generated by medical devices** (including those from mobile health / IoT)**, learn how to manage or recover from diseases, develop our understanding of health linked to genetic, genomic data etc.**

AI together with Big Data is seen as a key opportunity to the sector to identify new targets and biomarkers and to develop enhanced therapeutic molecules. There is a current debate about how much AI will disrupt the drug discovery process, where some see great opportunities while other are less optimistic about its impact[95], and the improvement to date are mixed. A report commissioned by the Wellcome trust[96] explored the current use and potential of AI in drug discovery. It identified five areas in which it can be deployed: understanding diseases, design and optimisation of small molecules, vaccines as well as antibodies, and finally safety and toxicity of those therapeutics. It showed that there is an intensification of the research in the areas of target discovery and on the small molecules. These tools are developed by either new entrants, AI companies or startups focused on AI tools for drug discovery, and some existing pharmaceutical companies who are integrating AI in their current practices. The main barriers to adopt AI tools is partly in

[94] World Health Organization (2021). Generating evidence for Artificial Intelligence-based medical devices: a framework for training, validation and evaluation. 9789240038462-eng.pdf

[95] Lowe (2024). AI and Biology. https://www.science.org/content/blog-post/ai-and-biology; Guadalupe Hayes-Mota, 2024, AI's Role In Revolutionizing Drug Development. https://www.forbes.com/councils/forbesbusinesscouncil/2024/09/26/ais-role-in-revolutionizing-drug-development/; Guadalupe Hayes-Mota (2024). AI Is Rapidly Transforming Drug Discovery. https://www.forbes.com/councils/forbesbusinesscouncil/2024/02/29/ai-is-rapidly-transforming-drug-discovery/

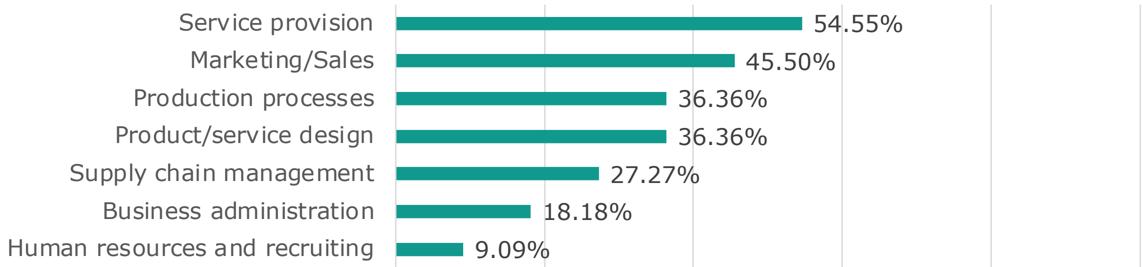
[96] Boston Consulting Group commissioned by Wellcome Trust (2023). Unlocking the Potential of AI in Drug Discovery. https://www.bcg.com/publications/2023/unlocking-the-potential-of-ai-in-drug-discovery

the availability of high-quality data[97], beside the problem of skills and labour and also trust, ethical aspects and transparency in these systems.

According to the results of the EMI Enterprise survey in 2024, for those companies in health that have adopted AI technologies, over 36% develop these systems using both their own employees and external service providers, over 36% develop these relying solely on their own employees, while 27% depend exclusively on external service providers. When health businesses use service providers, 56% use service providers based in their own countries, 22% rely on providers within the EU27 and another 22% rely on providers from the USA.

A breakdown of the use of AI within health company gives more details into the stage of operation where AI is used (see Figure below). AI is most commonly used in service provision, with **55%** of health businesses reporting its use; followed by **marketing and sales** at **45%,** and **product and service design** as well as **production processes**, both with an equal share of **36%.**

Figure 21: Share of companies using AI by business operation stage (pharma and medical devices)



Source: EMI Enterprise Survey 2024

The EMI Survey 2024 also reports that while AI is adopted by many firms in the health industrial ecosystem, the positive return to the business is overall still moderate. Half of the respondents (55%) have reported that AI has contributed to an **increase of their productivity**, ranging from 2% to 40%, while the remainder (45%) have reported no change in terms of productivity. **27%** of health businesses report that AI has **decreased their production costs**, while the remaining **73%** have reported **no changes**. Finally, a minority of businesses (**9%** of respondents), reported that **AI has allowed them to manage their company with fewer employees**, while the majority (**91%**) stated that it **has not reduced their need for staff in operations**.

Cloud Computing: Adoption and impact on industrial competitiveness

Cloud technologies are mainly related to the scalability of computation, the ability to perform complex analysis combined with an increasing volume of data. These computation capabilities are based on a shared pool of computing resources usually built as a network. Cloud Computing is used usually as an on-demand service, saving companies the cost of investing into High Performance Computing infrastructure. Cloud computing technology in the domain of health enables the analysis or re-analysis of pre-existing or archived data, as well as enabling the analysis of different types of data through collaborative platforms (such as biobanks and genomic data) that has the potential accelerate drug discovery[98]. This advanced digital technology is clearly linked to other advanced digital technologies such as Big Data in the sector to process large amount of data produced in the sector, from genomic data to data related to clinical studies, patient health records, and data generated by medical devices (IoT). The computing resources of Cloud Computing combined with Big Data can then be analysed by AI tools to generate valuable insights as described above.

Cloud Computing is one of the advanced digital technology most adopted by companies in the health industrial ecosystem (see Figure below), thus playing an

[97] Boston consulting and Lowe (2024). AI and Biology. https://www.science.org/content/blog-post/ai-and-biology
[98] OECD (2021). Building and sustaining collaborative platforms in genomics and biobanks for health innovation. https://doi.org/10.1787/23074957

important role in the ecosystem. Three quarters of the companies surveyed have been using Cloud Computing services for five to ten years, while another quarter have only been using Cloud Computing services more recently, for the past two to three years. The importance of Cloud Computing is shown in the planned investments of the EMI survey respondents. **57% of health businesses plan to invest 1-5% of annual turn-over on Cloud Computing next year, while 14% plan to invest 6-10%**.

The EMI Enterprise survey has highlighted that **51%** of those health businesses who have adopted Cloud Computing technologies, reported a **productivity boost**, with 42% reporting an increase between 5% and 10%. Thus, 49% of those health business who have adopted Cloud Computing technologies reported no impact on their productivity. The majority (56%) of businesses in health using Cloud Computing reported no change in **production costs**, a quarter report a decrease in production costs linked with the adoption (26%) ranging from 0.05% to 20%, while 19% reported an increase in production costs which ranges between 0.02% to 1%.

Other advanced digital technologies adopted in the health industrial ecosystem

Big data consists of the collection and or use of vast quantities of data, often needed for building powerful AI applications. The report listed above the wide-ranging applications of AI in the health industrial ecosystem. In many cases building strong AI models requires the availability of large datasets collecting data from health sensors (see IoT below), genetic and genomic data, etc. Industry relies on the large datasets and reliable datasets in order to build innovative and competitive products built on advanced digital technologies. Hence the policy push for the development of a health data infrastructure is an important policy in this direction as noted in the introduction to Section 3. The EMI Enterprise survey reported that **18% of businesses reported the adoption of big data,** showing an increase of 3 percentage points compared to the 2023 survey. **Experts view the European Health Data space as an important resource, as the sector has a problem with fragmentation of data.** Experts in the field have also raised the question of access to the European health data space, and expressed that wide access is often restricted to large companies which may limit opportunities. In terms of access to data, fragmentation persists due to varying regulations across countries both within the EU and globally, where some countries are much more stringent in terms of data protection. It has also been highlighted that privacy is an important aspect of these data, and regulations such as GDPR may nevertheless hinder the secondary use of the data. Indeed, **health data pose specific security and privacy threats due to the nature and sensitivity of health data**. Cyberhackers can exploit vulnerabilities to disrupt services or block the use of digital systems and therefore affect the normal delivery of healthcare services. When there is a breach, it can be relatively costly to address it, these were reported to have cost 19.3 billion euros in 2020 [99] . Furthermore, health data that are personally identifiable are more valuable than in other industries (€167 vs €148[100]), which makes health data a particular target for cybercrime. Some areas for improvement to mitigate digital security risks are relatively low-cost (such as training staff and monitoring programmes).

As discussed in the paragraph about AI, Big Data solutions are key for drug discovery and biopharmaceutical manufacturing, through the creation of integrated datasets of siloed data system (e.g. genetic information, clinical data etc.). The integration of this data can make a huge difference in the development of AI model but also requires appropriate hardware and software solutions to deal with the increasing and ever-growing volume of data. Indeed, suitable open-source datasets are of insufficient quality or proprietary databases are difficult to access for academics, finally there is a limited interoperability of

[99] OECD (2023). Fast-Track on digital security in health, 164. https://doi.org/10.1787/c3357f9f-en
[100] Originally reported as 180 US dollars vs 161 US dollars. Converted to euros using the average conversion in 2020 which is 1 dollar for 0.92 euros.

existing datasets due to use of different system, inconsistencies in data structures, lack of data standards[101], which are all factors hindering the development of AI systems.

Blockchain technology main domain of applications is in the domain of security, privacy and safety but also ensuring the authenticity of the data[102]. As seen above the health industry digital transformation relies on the ability to collect and use big datasets, many linked to patient information that are sensitive data. Blockchain is a tool to manage privacy and at the same time enables to identify fake data potentially influencing decision making and health outcomes. The advantage of Blockchain is that data is held in a decentralised manner by users and can be checked at regular interval to see whether attackers attempted to access the data. The EMI survey reported that **8% of businesses reported the adoption of blockchain technology,** showing an increase of 5 percentage points compared to the 2023 survey. A set of potential applications are developed in the PharmaLedger project[103] financed by the innovative health initiative, such as electronic product information of medications that stays up to date for the patient, making clinical trials data more secure, or the improvement of supply chain management to avoid counterfeit of medical products.

Internet of Things (IoT) involves physical devices connected to a network, usually the internet, and where its state can be altered using that network. These connected devices have usually the ability to collect data about their state or their environment through a variety of sensors[104]. The EMI survey reported that **31% of businesses reported the adoption of IoT, which is a significant part of the businesses surveyed** showing a steep increase from the 2023 survey, where 20% of respondents reported its adoption. In healthcare, this includes a range of applications including mobile health (or 'mhealth') or technologies of assisted living, which in particular includes wearables for care, diagnostics, medical devices, therapy, monitoring of elderly – mixed with Big Data[105].

Digital twin[106] "is a virtual replica of a living or non-living physical entity", creating a simulation of someone or something based usually on data collected from smart devices, the Internet of Things, or sensors that collect data continuously. This virtual replica can be used to test scenarios and make predictions using AI. For healthcare it can help to diagnose patients quicker, it can help also to develop personalised medicine and reduce healthcare costs. The drawback of digital twins is that they are costly to develop. The EMI survey reported a limited adoption of the technology with only **4% of businesses reporting its adoption.** Applications also include creating behavioural models of individuals and groups, which can help with understanding the effectiveness of healthcare interventions, it can also help with emergency and risk management.

Virtual Reality has two main domains of applications, the applications used by medical professionals and the applications for use by patients. Virtual reality can be particularly helpful for surgery preparation or for visualising the patient autonomy in real time or for remote presence. It can also help with diagnostics through 3D visualisations. Finally, it can prove very useful for training of students and staff for a variety of situation or surgery. The EMI survey reported a limited adoption of Virtual Reality with only **2% of businesses reporting its adoption.** For patients, there has been the development of several therapies

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[101] Boston Consulting Group commissioned by Wellcome Trust (2023). Unlocking the Potential of AI in Drug Discovery. https://www.bcg.com/publications/2023/unlocking-the-potential-of-ai-in-drug-discovery

[102] D. Burgwinkel, R. Bergström (2018). BLOCKCHAIN IN DIGITAL HEALTH AND LIFE SCIENCES, Eurohealth, 24, 3. https://iris.who.int/bitstream/handle/10665/332600/Eurohealth-24-3-11-14-eng.pdf?sequence=1&isAllowed=y; https://www.ihi.europa.eu/projects-results/project-factsheets/pharmaledger

[103] https://www.ihi.europa.eu/projects-results/project-factsheets/pharmaledger

[104] OECD (2023). Measuring the Internet of Things, OECD Publishing, Paris, https://doi.org/10.1787/021333b7-en.

[105] ECD (2023). Measuring the Internet of Things, OECD Publishing, Paris, https://doi.org/10.1787/021333b7-en and Haute Autorité de santé (2021). Évaluation des Applications dans le champ de la santé mobile. https://www.has-sante.fr/upload/docs/application/pdf/2021-06/criteres_de_qualite_du_contenu_medical_referencement_mhealth_ens_2021-06-30_10-58-28_773.pdf

[106] S. Nativi et. al (2022). MyDigitalTwin: Exploratory Research report, JRC Research Report. https://op.europa.eu/publication-detail/-/publication/96f69d62-f81c-11ec-b94a-01aa75ed71a1 ; Government Accountability Office (2023). Digital twins—virtual models of people and objects. https://www.gao.gov/assets/gao-23-106453.pdf

ranging from mental health disorders, management of pain or rehabilitation. It can also help patients to visualise a medical procedure or help assist people with disabilities [107].

The adoption of advanced manufacturing and robotics within the health ecosystem is increasing rapidly and is expected to grow further in the future[108]. In clinical settings and operating rooms, robots support healthcare professionals by enhancing precision and improving patient care outcomes. In research laboratories, robotics streamline manual, repetitive, and high-volume tasks, enabling technicians and scientists to dedicate their expertise to more strategic and innovative endeavours.

AI is transforming healthcare by improving diagnostic accuracy, enabling earlier disease detection and enhancing patient outcomes[109]. Meanwhile, big data analytics allow for the examination of large datasets encompassing thousands of patients, thereby improving decision-making processes with real-time insights. Additionally, IoT technologies are transforming the health ecosystem by enabling remote monitoring, personalised treatment plans, and more efficient healthcare delivery[110]. Other digital technologies as cloud computing, blockchain, digital security and cybersecurity, and AVR are less represented among health-focused technology centres.

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[107] European Commision (2023). Extended reality. Opportunities, success stories and challenges (health, education): final report. https://op.europa.eu/en/publication-detail/-/publication/f242f605-a82e-11ed-b508-01aa75ed71a1

[108] De Micco, F., et al. (2024). Robotics and AI into healthcare from the perspective of European regulation: who is responsible for medical malpractice?. Frontiers in Medicine, 11, 1428504.

[109] https://digital-strategy.ec.europa.eu/en/library/artificial-intelligence-healthcare-report

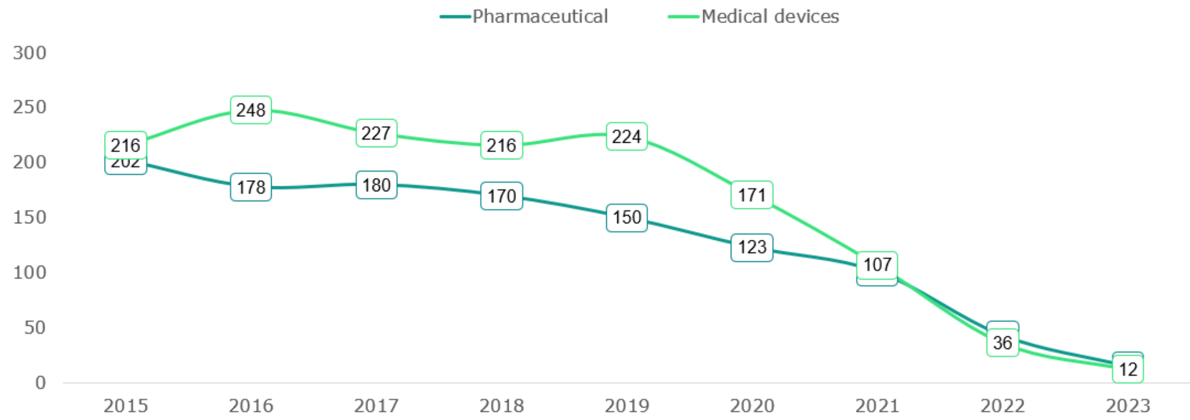
[110] Li, C., et al. (2024). A review of IoT applications in healthcare. Neurocomputing, 565, 127017. https://www.sciencedirect.com/science/article/pii/S0925231223011402

3.1.3. Development of health startups in the field of digital

This section analyses to what extent the digital transition of the industrial ecosystem is supported by innovative tech startups and underpinned by technology development. Beyond the simple adoption of pre-existing digital technologies by health businesses, to stay at the edge of the technological frontier there is a requirement for companies to develop their own technology and innovating in the area. This is highlighted in this section by the role played by the creation of innovative companies in the ecosystem and private investments in the area.

The development of new digital technologies and innovations in the health industrial ecosystem can indeed be measured by the creation of new digital startups in the area based on Crunchbase data (see Figures below). Over the period from 2015 to 2019, the number of digital startups in the health industrial ecosystem was stable with around 400 new startups created per year. There were slightly more startups focusing on medical devices compared to startups focusing on pharmaceuticals. Since 2019, there is a slowdown of creation of digital health companies according to Crunchbase data, which is in line with overall trend observed in Crunchbase with a lowering of the number of new startups[111](for 2022 and 2023 these may still increase as data is retroactively added to the database).

Figure 22: Creation of digital startups in the health industrial ecosystem

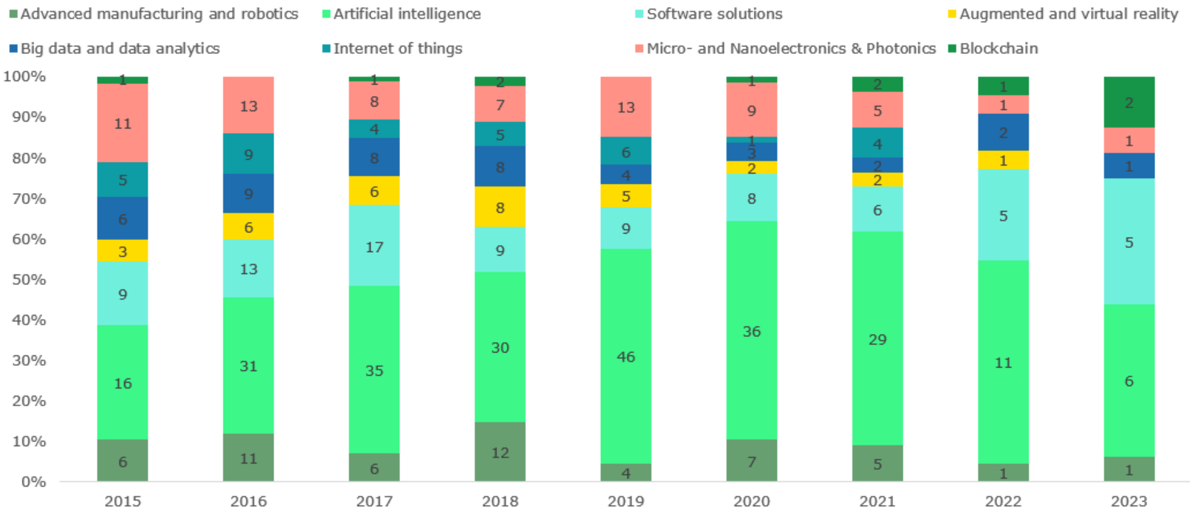


Source: Technopolis Group based on Crunchbase and NO

Looking into the type of advanced digital technologies used by startups in the health industrial ecosystem, a majority of new startups use AI. **The number of startup creation** in the health industrial ecosystem **using AI increased from 16 creations in 2015 to 46 startup creation in 2019,** but since then has seen a downward trend. Other advanced digital technologies used by startups in the health industrial ecosystem are in the area of software solutions (over 80 startup creations since 2015), micro- and nanoelectronics and photonics (over 60 startup creations since 2015), advanced manufacturing and Robotics (over 50 startup creations since 2015). Software solutions saw an increase in startup creations up until 2017 with 17 creations and had annual creations between 5 and 10 startups per year since then. For micro- and nanoelectronics and photonics, there were more startup creations in the 2010s (between 7 and 13 creations per year), but has been on a decreasing trend since 2021 with 5 or less creations per year since then. Advanced manufacturing and Robotics follow a similar trend with higher number of creations until 2018 (ranging between 5 and 12 per year) and has reduced to five or less creations per year since 2021.

[111] See: https://news.crunchbase.com/venture/startup-creation-challenges-opportunities-charts-sagie/

Figure 23: Digital technologies used by startups in the health industrial ecosystem



Source: Technopolis Group based on Crunchbase and Net Zero Insights

These startup creations represent a range of technologies, domains of applications in health.

In the field of AI, new companies are emerging in pharmaceuticals sector, particularly in AI-driven drug discovery. For instance, **Aqemia** is leveraging AI to push the boundaries of drug discovery with its 'Pharma 3.0' model, accelerating the development process and making it more efficient. Similarly, AI for clinical decision support is another key use case. **Pure Functionals**, for example, provides AI-powered analytical solutions that enhance clinical decision-making, helping healthcare professionals make more informed choices for their patients. For medical devices startup creations, AI is being used extensively for disease detection and prevention. A notable example is **U-Care Medical**, which has developed AI-based algorithms to detect and prevent kidney diseases, offering early diagnosis and in turn better outcomes. When it comes to patient care and management, **Tensormedical** stands out by developing AI tools that improve the care of patients with multiple sclerosis, providing automated analysis that enhances the treatment process.

There are a number of startups developing new software solutions for both pharmaceuticals and medical devices. These technologies help for instance to streamline operations or improve process management. For example, **Opeaz** provides a software platform specifically designed for the pharmaceutical industry, simplifying the management of relationships and operational workflows. This helps pharma companies manage complex operations with greater efficiency. Another key player is **QbD Software N.V.,** which offers SaaS (software as a service) solutions for companies in pharma, biotech, and medical devices. Their software helps manage quality, processes, and product-related tasks, ensuring compliance and operational excellence.

Finally, there are also a number of micro and nanoelectronics & photonics startups providing innovative solutions in the health industrial ecosystem. These include innovative ophthalmic devices being developed to improve eye care and surgical procedures. For instance, **Viltreo** *Care* produces ophthalmic instruments designed for eye care professionals, helping them provide more precise and effective treatments. On the cutting edge of eye surgery innovation, **EyePCR** has developed breakthrough technology that addresses challenges in cataract and refractive lens exchange surgeries, reducing complications experienced by patients following these procedures.

3.1.4. Private investments

This section analyses the trends in the private investments into the digital transition. Private investments are another key indicator to understand the digital transformation of the health industrial ecosystem as it shows both how established and new companies are investing in the technology, but also how private investors such as venture capitalists invest in new ventures in the health sector.

The Figure below shows the current and planned investments of businesses in advanced digital technologies relative to their annual turnover as reported in the EMI survey 2024. **The largest level of investment in advanced digital technologies is focused first on big data, robotics, cloud computing and edge computing where over 75% of companies reported an investment between 1% and 10% of their annual turnover.** For Big Data 25% of businesses surveyed aim to invest 6-10% of their turnover in the technology, for robotics over 22% or in cloud computing 21% of businesses surveyed aim to invest 6-10% of their turnover in these technologies. For AI technologies, the proportion of the foreseen investments by companies are relatively less compared to other digital technologies mentioned with just over 55% of businesses planning in investing between 1 and 10% of annual turnover in this technology.

Figure 24: Level of investment of businesses in health into digital technologies

	Cloud	Robotics	IoT	Big Data	AI	AVR	Blockchain	Edge computing	Digital Twins
Less than 1% of annual turnover	21.62%	22.22%	42.86%	12.5%	45.45%	100%	25%		
1-5% of annual turnover	56.76%	44.44%	42.86%	62.50%	27.27%		50%	100%	50%
6-10% of annual turnover	21.62%	22.22%	7.14%	25%	18.18%				
11-30% of annual turnover									
More than 30% of annual turnover									

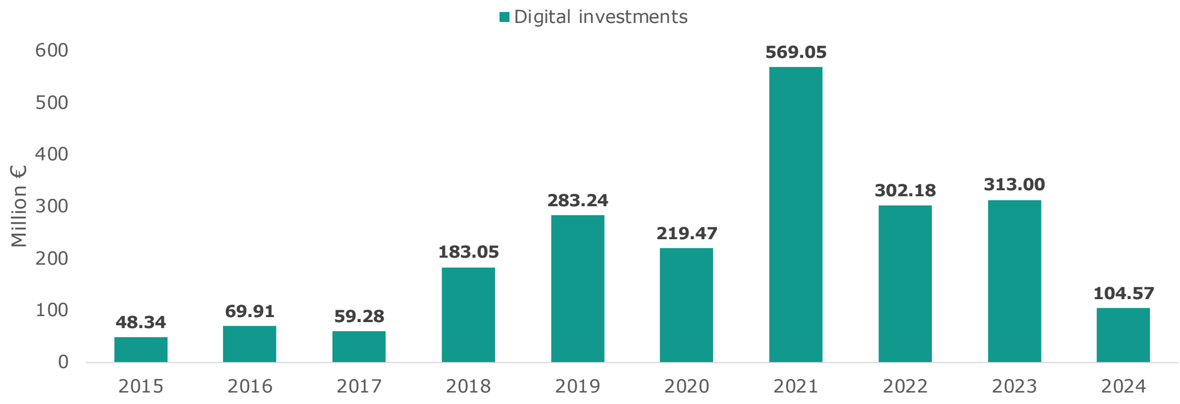
Source: EMI Survey 2024

Venture capital investments

Venture capital investments into young companies focusing on the digital transition in the health industrial ecosystem are rapidly transforming the landscape by supporting the development of innovative health solutions and improve overall helth outcomes. The Figures below show the volume of venture capital investment into MedTech companies focusing on the digital transition of the health industrial ecosystem.

The trend of increasing investments shows a general upward trajectory in venture capital investments between 2015 and 2023, rising from around €50 m in annual venture capital investments in new ventures to over €300 m per year in 2023. However, 2020 and 2021 were exceptions to this overall trend. In 2020, there was a slowdown in investments, while 2021 saw exceptionally high venture capital investment, more than double the recorded figure of 2019.

Figure 25:Venture capital investments into the health young companies supporting the digital transition

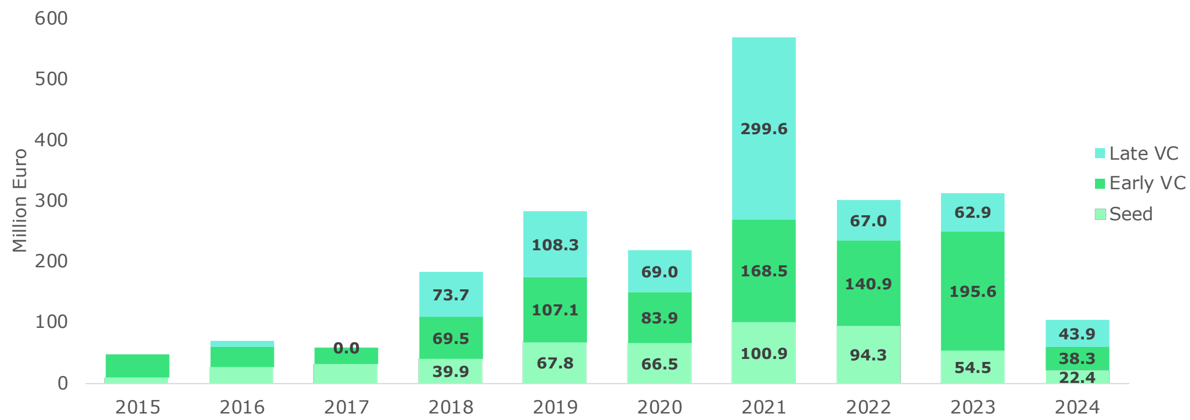


Source: Technopolis Group based on Crunchbase and NO

These exceptional trends are probably linked to a renewed interest in MedTech startups overall following the COVID-19 pandemic[112], where digital health startups also benefit from this trend.

Figure 32 shows that this trend includes all types of investments from seed funding to early venture capital investments. The high level of investments in 2021 is driven by an exceptional year of late venture capital investment with around €300 m invested. Between 2022 and 2023, late capital investment in health startups focusing on digital transitions has been stable between €60 m and €70 m per year. Early venture capital investment since 2015 is still on an upward trend with a peak investment in 2023 over €190 m. Finally, seed investments have also been on an upward trend since the mid-2010s peaking in 2021/2022 with an annual investment of around €100 m per year.

Figure 26: Venture capital investments into the digital transition of health startups



Source: Technopolis Group based on Crunchbase and NO

Most investments are directed toward AI startups, with substantial annual investments ranging from EUR 190 m to €380 m since 2021. A notable example of a European MedTech startup focusing on AI is **Volta Medical**[113], an AI-driven company developing intelligent software solutions to guide cardiologists during interventional

[112] Financial Times (2020). Pandemic provokes new wave of funding for healthcare startups. https://www.ft.com/content/3a15886c-9861-4373-98cf-4846cff9879c; Silicon Valley Bank (2023). Future of Healthtech 2023. https://www.svb.com/globalassets/trendsandinsights/future-of-healthtech-report-2023_final.pdf

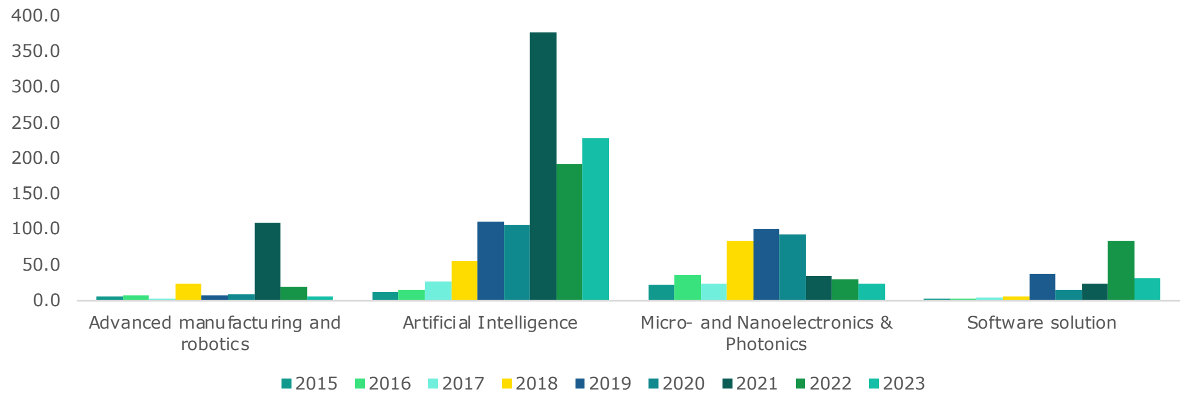
[113] https://www.volta-medical.eu/de

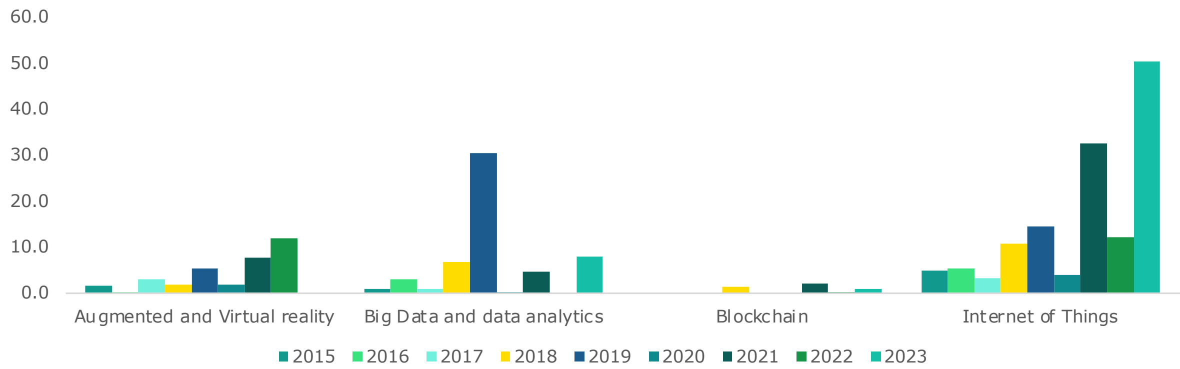
procedures. Founded in 2016 in France, Volta Medical has raised €61.23 m and now offers products certified as compliant with EU regulations (CE mark) and approved by the FDA.

Micro and Nanoelectronics & Photonics have also seen significant venture capital investments, totalling over €445 m between 2015 and 2023. The strongest investments in startups focused on these technologies occurred between 2018 and 2020, with €80 m to €100 m invested annually. Software solutions, advanced manufacturing, and robotics have also attracted considerable investments, with €206 m and €189 m invested over the same period, respectively. Advanced manufacturing and robotics saw a particularly strong investment year in 2021, with over €100 m invested. A notable startup in this area is **eCential Robotics**, a company dedicated to 2D/3D imaging and computer-assisted minimally invasive surgery. Founded in 2009 in France, eCential Robotics has raised €25.66 m to date.

For software solutions, 2022 was an outstanding year in terms of venture capital investments, with €84 million invested. **PrediSurge**, a software company offering design and support solutions for physicians and medical device companies—especially using digital twin technology—achieved significant investment. Founded in 2017, PrediSurge has raised €10.42 million.

Figure 27: Venture capital investments by advanced digital technologies into MedTech startups





Source: Technopolis Group based on Crunchbase and NO

Venture capital investments in startups focusing on other advanced digital technologies is moderate compared to the technologies mentioned above. Internet of Things startups in the health industrial ecosystem have totalled more €130 m investment since 2015, with an increase in recent year (over €50 m in 2023). Startups in the health industrial ecosystem focusing on Big Data and analytics raised over €50 m since 2015. **LiveMetric** is one of these startups, a medical device company developing non-invasive sensing (such as blood pressure and heart rate monitoring wrist bands), and deep data analytics solutions. Founded in 2016, they have raised €21.42 m.

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

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

Public funding

- The European Regional Development Fund (ERDF) plays an important role in the digital transition of the health industrial ecosystem. For health-related projects, ERDF projects dealing with digital transformation covered around **22% of the projects** and **28% of the funding**.

- Within the ERDF funding, **AI and big data receive the most attention, representing 17% and 12% of the investment in the digital portfolio for the health industrial ecosystem, respectively.**

- In Horizon Europe, 40% of the projects related to health focused on the digital transition.

Skills

- According to **Cedefop data 36% of job advertisements in the health industrial ecosystem require digital skills, 23% require moderate digital skills, and 13% advanced digital skills.**

- A LinkedIn analysis reflects that, there is an increase of advanced digital skills demand among healthcare workers between 2022 and 2024.

Co-location of technology centres and clusters

- Germany and France are hotspots for leading **cluster organisations and renowned technology centres in the health ecosystems,** followed by **Italy and Belgium.**

Beyond private investments by existing companies, or by investors in young companies, a successful digital transition also relies on framework condition existing within the industrial ecosystem. This includes the technology generated, public investments in the system as well as the skills held by the workforce in the system, which are crucial for fostering innovation.

3.2.1. Public investments supporting the digital transition

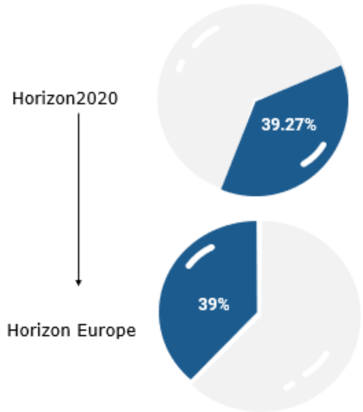
Public investments in the health industrial ecosystem plays also an important role to enable the digital transformation. In this section we particularly focus on the EU investment in R&D through the Horizon 2020 (2014-2020) and Horizon Europe (2021-2027) funding programme and the Cohesion policy, in particular the European Regional Development Funds (ERDF). These funding programmes are specifically designed to strengthen research and innovation, which in turn improve economic growth by funding innovative projects, and teams involving public and private stakeholders.

EU Research and Development Framework Programmes

Horizon 2020 data was analysed with regard to digital transition related investments within the health industrial ecosystem. 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 a total of 839 projects classified under health.

Figure 34 looks at the Horizon 2020 (investments on the period 2014-2020) and the latest Horizon (2021-2027) Europe programme. The share of digital transition projects in the health ecosystem has remained stable between the two programmes, with around 40% of projects concerned.

Figure 28: Share of Horizon 2020 and Horizon Europe health projects that contribute to the digital transition



Source: Technopolis Group based on Cordis

Several examples of health projects funded under Horizon 2020 and Horizon Europe supporting the digital transition are described in the Box below.

Box 2: Horizon 2020 and Horizon Europe Health projects supporting the green transition

Horizon 2020 funded the P3DNavitech[114] (Novel navigation system for arthroscopy that uses solely the endoscopic video to perform measurements inside the joints and provide the necessary guidance to the surgeon) project1 that started in 2015. Perceive3D (P3D) has developed a novel navigation system for arthroscopy that uses solely the endoscopic video to perform measurements inside the joints and provide the necessary guidance to the surgeon. Such system will be the first navigation solution that eliminates the need of external optical tracking of camera/tools, or the need of expensive capital equipment for imageology in the operating room. The navigation is done using the video information only and, based on P3D's proprietary camera calibration technology and advanced computer vision techniques, and the captured endoscopic image provides all the necessary geometric information.

Horizon Europe funds the project OMICSENS[115] (integrated nano-photonic OMICs bio-SENSor for lung cancer). The OMICSENS project, started in 2024, aims to develop a radically new omics measurement platform that would be initially applied to improve non-small cell lung cancer (NSCLC) prognosis by ensuring a timely and accurate detection of Tyrosine Kinase Inhibitor (TKI) resistance associated to Epidermal Growth Factor Receptor (EGFR) mutations. Subsequently, OMICSENS will be used to improve prognosis of patients suffering from other types of cancers. OMICSENS targets the creation of the first nano-photonic integrated omics bio-sensor to tackle TKI resistance and improve NSCLC treatment outcome and patient prognosis. Thanks to OMICSENS, we will build a six layers technology comprised of an on-chip embedded infra-red source arrays, an artificial intelligence optimised nano-structured surface for photonic signal enhancement, a functionalised surface of high absorbance to specific analytes, a microfluidics system to deliver the sample, a metamaterial-based photo detector array with optimised quantum efficiency and an AI algorithm enabling analyte quantification.

Source: authors based on Cordis

European Regional Development Fund

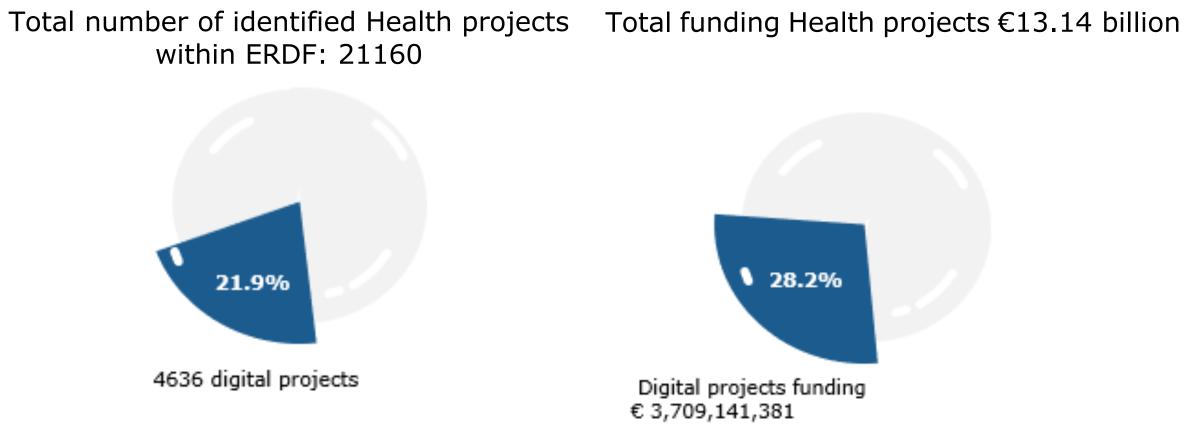
A key source of public funding that enables the digital transition is the European Regional Development Fund (ERDF). For this analysis, two data sources have been used and merged, namely the Cohesion Open Data maintained by the European Commission and the Kohesio data.

ERDF provides funding to EU regions to tackle disparities between regions and provides fund for infrastructure or to support SMEs in their digital transformation or to support innovation. The Figure below shows that ERDF projects dealing with digital transformation

[114] P3DNavitech. https://perceive3d.com
[115] OMICSENS. https://www.omicsens.eu

covered around 22% of the projects (4636 projects with a digital focus) and 28% of the funding within the projects identified and associated funding of the health industry, representing €3.7 bn. Many digital health projects focus on the digitisation of health services, or the provision of e-health services in different EU regions[116].

Figure 29: Share of projects supporting the digital transition within the health industrial ecosystem

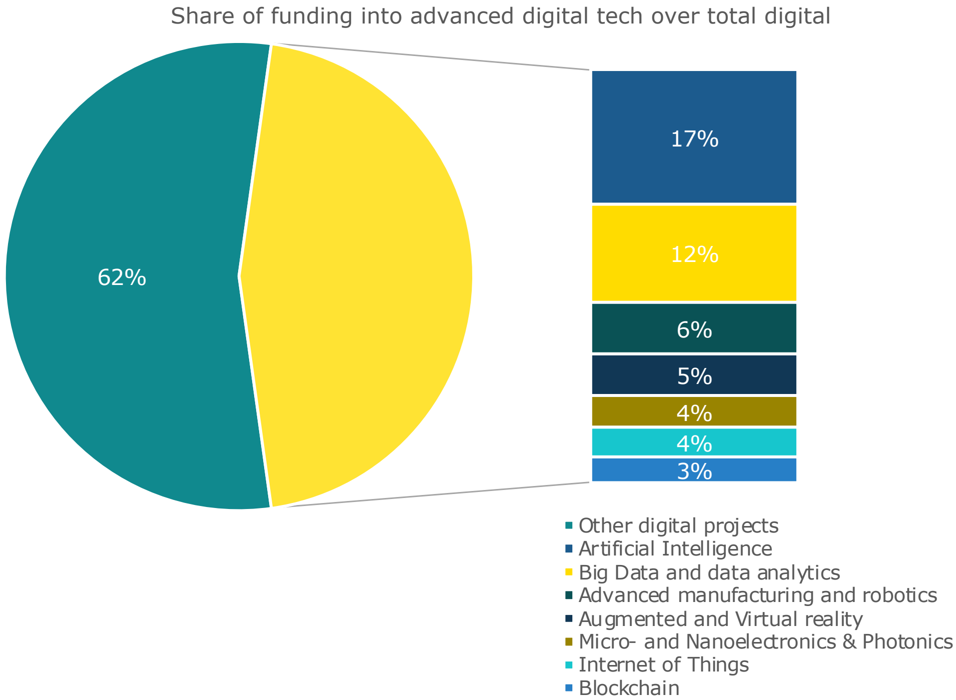


Source: Technopolis Group based on Cohesio

Looking at these ERDF digital projects focusing on the health industrial ecosystem, a large share (38%) is dedicated to advanced digital technologies. **Similar to private investments, AI and big data receive the most attention, representing 17% and 12% of the digital portfolio for the health industrial ecosystem, respectively.** However, these projects cover a wide range of advanced digital technologies, including advanced manufacturing and robotics, augmented and virtual reality, micro and nanoelectronics & photonics, the Internet of Things, and blockchain.

[116] See Kohesio data of the European Commision: https://kohesio.ec.europa.eu/en/projects?theme=Information-and-communication-technology&policyObjective=Smarter-Europe&keywords=health&fund=ERDF---European-Regional-Development-Fund

Figure 30: Share of funding into advanced digital technology over total digital technology



Source: Technopolis Group based on Cohesio

A number of examples of ERDF projects are shared below in order to give additional insights as to the type of work financed in this programme focusing on advanced digital technologies.

Project: ESKULAP	Technology: **Big Data and data analytics**
The project **ESKULAP** (Electronic System of Computer Medical and Pharmacy Services for Patients in the District Hospital in Tarnowskie Góry) will provide functionalities enabling the launch of a repository of Electronic Medical Documentation (EDM) and data processing, in order to support the production of medical record supported by information and communication technologies. Budget: Total cost €1 000 119.20; EU contribution €850 101.25 Duration : October 2019 - June 2023 **Source**: **https://kohesio.ec.europa.eu/en/projects/Q4426756**	
Project: The virtual human body	Technology: **Augmented/Virtual reality**
The consortium aims to develop virtual interactive human anatomy platform for training healthcare professionals. Budget: Total cost €548 406.12; EU contribution €472 208.86 Duration: April 2017 - July 2019 **Source**: **https://kohesio.ec.europa.eu/en/projects/Q3988795**	
Project: BioRAMASCOPE	Technology: **Micro and nanoelectronics & photonics**
This project aims to invest in infrastructure, and capacities and equipment of SMEs linked to research and innovation activities by investing in the collaboration of P. J. Šafárik University with SAFTRA Photonics s.r.o. and AUSYS s.r.o.. Th consortium aims to develop a rapid test to detect SARS-CoV-2 viruses to be captured on the surface of photonic nanostructure chips.	

Budget: Total cost €3 060 199.77; EU contribution €1 935 624.64 Duration: January 2021 - January 2023 **Source: https://kohesio.ec.europa.eu/en/projects/Q3107859**	
Project: MEDIIOCHAIN	Technology: **Blockchain**
MEDIIOChain aims to develop a health information management system using Blockchain technology. It will take the form of a distributed register of aggregated health information relying on advanced crytopgraphic mechanisms based on Blockchain technology. Budget: Total cost €5 221 085.80; EU contribution €3 718 854.22 Duration: February 2020 – August 2023 **Source: https://kohesio.ec.europa.eu/en/projects/Q4414660**	

3.2.2. Digital skills

A successful digital transformation of the health industrial ecosystem should ensure that workers are adequately trained to use digital technologies. WHO reported that training is offered to health professionals as part of their continuous education, but these may not be mandatory[117]. To enable the benefits from the digital transformation, there is a need for the development of digital skills both for the healthcare profession, but also for companies focusing on the development of medical devices and therapeutics to work on their digital transformation.

2023 was the European Year of Skills, where both digital and green skills are the focus of this policy initiative[118]. Following the results of this initiative, it remains a high priority for the EU to enhance the digital skills of individuals (ibid.). This is also an increasing priority for the health and care services with an ambitious target of key public services that should be accessible online, with a specific target of 100% of electronic health records[119].In 2023, the European Commission has launched a pact for skills setting out the objectives of the skills partnership to tackle the specific challenges of the healthcare sector, where digital transformation is one of the main challenges to be tackled[120]. In 2024, the European Commission has published its Pact for skills in the large scale partnership for the health ecosystem, setting a clear commitment and target, that 10% of health professionals should participate in reskilling and upskilling in digital skills annually by 2030 (representing 1.5 million of workers concerned per year). Re-skilling and up-skilling for long term care staff is also a priority for the European Commission, especially to deliver transformation resulting from the digitalisation of the sector[121]. The proficiency in digital skills of health and care worker is therefore key to achieve this transformation, but also a challenge since they represent over 4% of the EU population[122]. A pact for skills roundtable for the health

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[117] World Health Organization (2024). Exploring the digital health landscape in the WHO European Region: digital health country profiles. https://www.who.int/europe/publications/i/item/9789289060998
[118] https://digital-skills-jobs.europa.eu/en/latest/news/results-european-year-skills
[119] European Commission (2023). Cardinal points - Digital Decade report 2023. https://digital-strategy.ec.europa.eu/en/library/cardinal-points-digital-decade-report-2023
[120] European Commission, 2023, The skills partnership for the European Health Industry. Accessed on 10/3/2025: https://pact-for-skills.ec.europa.eu/document/download/0e87bd80-fce8-48ef-b055-ca275f9d94c4_en?filename=Large%20Scale%20Partnership%20for%20the%20European%20Health%20Industry%20Manifesto.pdf
[121] BeWell, 2024,Pact for skills: Large Scale Partnership for the Health Ecosystem. Accessed on 7/3/2025: https://pact-for-skills.ec.europa.eu/document/download/2db50654-713d-4777-9679-0018a83f87ec_en?filename=Skills%20Partnership%20for%20the%20health%20ecosystem_final_commitment%20edits.pdf; European Commission, 2023, Driving Up Training and Life Long Learning in Long-Term Care - a Skills Partnership. Accessed on 10/3/2025: https://pact-for-skills.ec.europa.eu/document/download/c5144184-7a6c-42a0-9106-113cb51870ae_en?filename=Driving%20Up%20Training%20%26%20Life%20Long%20Learning%20in%20Long-Term%20Care%2002-05.pdf
[122] BeWell consortium (2023). Skills Strategy for the digital & green upskilling and reskilling of the health and care workforce. https://bewell-project.eu/wp-content/uploads/2024/04/BeWell-Skills-Strategy-version-1.1-1.pdf

ecosystem[123] has highlighted that there is a pressing need to reskill and upskill healthcare workers digital skills, while not putting additional burden on these worker (these technologies should free up workers time, improve patient care and increase efficiency). The aspect of trust is also important due to patient safety, as well as the appropriate handling of clinical data by healthcare staff. These digital solutions should be embedded in normal care pathways, with an appropriate legal and financial basis. These technologies and training should be embedded in their day-to-day practice. These recommendations align with the findings of an OECD report on digital skills of the healthcare workforce[124]. These findings are especially important since the COVID-19 pandemic, there is a heightened shortage of health and care workers (problem with recruitment and retention linked to unattractive corking condition and employment), inefficient organisation of work, insufficient investment and skills mismatches not aligned to population health needs[125].

To provide insights into the skills demand and skills supply in the health ecosystem, this study draws upon two databases, namely the Cedefop database and LinkedIn[71].

Moderate digital skills have been defined following Cedefop[126] notably including "*five types of skills under the digital skills umbrella such as information processing (e.g. using a search engine and storing information and data); communication (including teleconferencing and application sharing); content creation (such as producing text and tables, and multimedia content); security (e.g. using a password and encrypting files); and, problem solving (e.g. finding IT assistance and using software tools to solve problems)"*. (The list of keywords that have been used to track LinkedIn is included in Appendix B).

Advanced digital skills have been defined as a specific group of digital skills in the context of the advanced digital technologies captured in this project notably by Artificial Intelligence, Big Data, Cloud Computing, Robotics, Internet of Things, digital security, augmented and virtual reality and Blockchain (the list of keywords that have been used and are possible to track with the algorithm of LinkedIn is included in Appendix B).

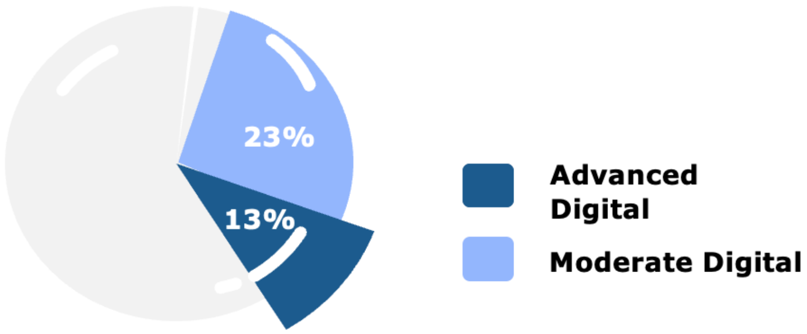
3.2.2.1. Skills demand

For the use of AI in drug discovery, the limited adoption of AI in drug discovery pipeline is limited in part in terms of capabilities of firms, including the skillset needed to understand AI and the ability to deploy these tools[127]. The needed skillset required are usually multidisciplinary, with a mix of AI skills or data science skills as well as expertise in drug discovery, and these profiles are currently lacking (ibid.). Developing multi-disciplinary teams combining a mix of people with this expertise presents also it's set of challenges as inter-disciplinary collaboration are difficult to put in place. Then finally, due to the shortage of these skillset, retaining these individuals are also a challenge.

An analysis of job advertisement (Cedefop data) shows that **36% of job advertisements in the health industrial ecosystem require digital skills, 23% requiring moderate digital skills, and 13% requiring advanced digital skills**.

[123] European Commission (2021). Pact for Skills Roundtable with Commissioners Kyriakides, Schmit and Breton for the health ecosystem. https://pact-for-skills.ec.europa.eu/community-resources/publications-and-documents/pact-skills-roundtable-commissioners-kyriakides-schmit-and-breton-health-ecosystem_en
[124] OECD (2021). Empowering the health workforce to make the most of the digital revolution. https://www.oecd-ilibrary.org/social-issues-migration-health/empowering-the-health-workforce-to-make-the-most-of-the-digital-revolution_37ff0eaa-en
[125] World Health Organization (2022). Health and care workforce in Europe: time to act. https://www.who.int/europe/publications/i/item/9789289058339
[126] https://www.cedefop.europa.eu/en/data-insights/digital-skills-challenges-and-opportunities
[127] Boston Consulting Group commissioned by Wellcome Trust (2023). Unlocking the Potential of AI in Drug Discovery. https://www.bcg.com/publications/2023/unlocking-the-potential-of-ai-in-drug-discovery

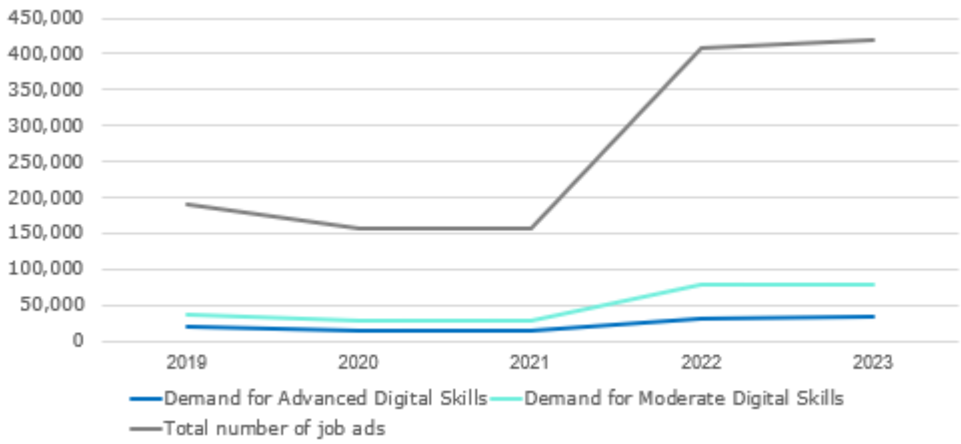
Figure 31: Share of the job advertisements in the digital transition in the health industrial ecosystem



Source: Technopolis Group based on Cedefop

The Figure below shows the evolution of job advertisements in the health industrial ecosystem since 2019 up until 2023, which shows a sharp increase in job ads since 2021 and the COVID-19 pandemic which up until 2021 were in the region of 150 000 to 200 000 job advertisements per year, but since 2022 there were over 400 000 job advertisements a year. The increase in job advertisements surely indicates an acute need for healthcare workers, but not necessarily a large increase in hiring. Indeed, there are a number of reasons why there is currently a high attrition rate of healthcare workers, including a high number of retirements, a higher rate of mortality since the COVID pandemic, migration and also resignation due to working conditions[128]. The working conditions as highlighted by recent strikes of the healthcare workforce in the number of European countries does not paint an attractive picture to entice entry on this job market[129].

Figure 32: Share of online job advertisements with a requirement for digital skills in health in the EU27



Source: Technopolis Group based on Cedefop

3.2.2.2. Skills supply

To gain insights into the supply of skilled professionals, the **LinkedIn database** has been consulted. LinkedIn is the largest professional network platform with rich information like profile summary, job title, job description and field of study, which can be used for the identification of skilled professionals with skills relevant to the green transition. In particular, advanced digital skills have been again defined as Artificial Intelligence, Cloud

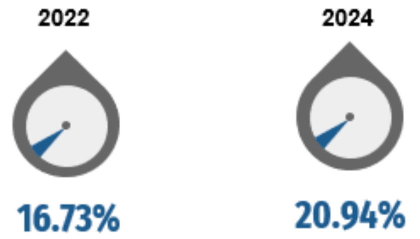
[128] World Health Organization (2023). From great attrition to attraction: countering the great resignation of health workers. https://iris.who.int/bitstream/handle/10665/372887/Eurohealth-29-1-6-10-eng.pdf?sequence=1

[129] World Health Organization (2023). The health workforce crisis in Europe is no longer a looming threat – it is here and now. The Bucharest Declaration charts a way forward. https://www.who.int/europe/news/item/22-03-2023-the-health-workforce-crisis-in-europe-is-no-longer-a-looming-threat---it-is-here-and-now.-the-bucharest-declaration-charts-a-way-forward

Computing, Big Data, Robotics, Internet of Things, augmented and virtual reality, digital security and Blockchain, but advanced software technologies have been also included that are relevant for the industrial ecosystem.

The Figure above shows that since 2021 there is an increase in demand for both advanced digital skills and even more moderate digital skills within health sector; but overall a reduction of the share of such advertisement including digital skills, which could be explained by tension on the health industrial ecosystem labour market. LinkedIn data provides a snapshot of the digital skills of the health workforce and shows that there is an increase of advanced digital skills among the healthcare workers between 2022 and 2024 as shown in Figure 39. This suggests that, while the market may not be fully reflecting the demand for digital competencies in LinkedIn job postings, the actual digital skill levels of health sector professionals are improving.

Figure 33: Share of professionals in health with advanced digital skills



Source: Technopolis Group based on LinkedIn

Experts highlighted that skills demand for advanced digital skills particularly for AI is growing exponentially, and the need for domain expertise is remaining stable and it needs an adaptation of the workforce and work strategy. Indeed, a transition to integration of advanced digital skills such as AI requires organisational change to break silos, and it trickle down to work practice[130]. Often it is better to hire people with skills in specialised digital knowledge rather than retrain but overall there is a lack of expertise on how to deploy these AI tools, and a lack of training on AI fundamentals to use the tools (ibid.). Recruitment can also be difficult in the sector because these skills are well thought after in a wide range of industrial ecosystems.

3.2.3. Demand for digital products and services

While it is important that the industrial sector enable their digital transformation, the novel products and services emerging from these transformations also need to be met by a growing demand.

The COVID-19 pandemic has changed people's perception of how digital technologies affect our life, but also **how they access and receive health services**. The Eurobarometer on the Digital decade shows that around 8 out of ten respondents expect accessing part of their health services through digital means[131], which shows the gaining dominance of digital technologies in the health industrial ecosystem. The Eurobarometer shows that citizens are also interested in how public actions shape the digital transformation, with more than 8 in 10 respondents thinking that there is a need to build efficient and securing digital infrastructures, and that there is a need to increase research and innovation to build a strong digital infrastructure.

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[130] Boston Consulting Group commissioned by Welcome Trust (2023). Unlocking the Potential of AI in Drug Discovery. https://www.bcg.com/publications/2023/unlocking-the-potential-of-ai-in-drug-discovery

[131] European Commission (2024). The digital decade, Special Eurobarometer 551. https://europa.eu/eurobarometer/api/deliverable/download/file?deliverableId=92894

During the COVID-19 pandemic, the use of telehealth and teleconsultation has increased[132] but there are still differences between age groups, younger people are keener to adopt these technologies, as well as people located in urban areas[133].

In the health industrial ecosystem, **there may be one additional barrier to digital adoption compared to other sectors which lies in the key importance of privacy and security of data as these are particularly sensitive**. Indeed, data privacy and digital security and the lack of transparency is an important aspect for both patients and healthcare workers in the adoption of these technologies[134] and the growing number of cyber-attacks[135] . Access to high quality and large volume of clinical and health data is a pre-requisite for developing better AI tools, thus aspects of security and privacy is key to ensure the long-term acceptance of these technologies.

3.3. Impact of digital technologies on industrial competitiveness

What is the impact of digital technologies on competitiveness?

-In the health ecosystem the impact of digital technologies is highly dependent on the availability of health data.

- Availability of health data has been a policy priority in the EU through its Digital Decade policy programme, and for the WHO which developed a **European regional digital health action plan for 2023-2030** to help countries scale up their digital transformation.

- At the national level, over 80% of EU countries have a digital health strategy with a strong priority on data access, reuse and information sharing, and now all members states have public funding available for digital health programmes.

Digital transformation is a key priority for policy makers in the EU, as shown by the variety of strategic documents and policy programmes with several of them being specifically focused on the health industrial ecosystem. This is embodied in the ambitious target to be achieved by 2030 through its Digital Decade policy programme[136]. Alongside these initiatives, the WHO European regions developed a **European regional digital health action plan for 2023-2030** to help countries scale up their digital transformation using four strategic priorities: *"(i) setting norms and developing technical guidance; (ii) enhancing country capacities to better govern digital transformation in the health sector and advance digital health literacy; (iii) building networks and promoting dialogue and knowledge exchange; and (iv) conducting horizon-scanning and landscape analysis for patient-centred solutions that can be scaled up*." [137].

Digital transformation in the health ecosystem is well under way in Europe as the WHO[138] has shown in their 2022 survey on digital health, with an accelerated transformation since

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[132] World Health Organization (2023). The ongoing journey to commitment and transformation: Digital health in the WHO European Regin 2023. https://cdn.who.int/media/docs/librariesprovider2/data-and-evidence/english-ddh-260823_7amcet.pdf?sfvrsn=4c674522_2&download=true

[133] European Parliamentary Research Service. (2021). The rise of digital health technologies during the pandemic. https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/690548/EPRS_BRI(2021)690548_EN.pdf

[134] OECD (2021). Empowering the health workforce to make the most of the digital revolution, 129. https://doi.org/10.1787/37ff0eaa-en

[135] OECD (2023). Fast-Track on digital security in health, 164. https://doi.org/10.1787/c3357f9f-en

[136] European Commission (2022-2023). Europe's Digital Decade: digital targets for 2030. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en

[137] World Health Organization (2022). Regional digital health action plan for the WHO European Region 2023–2030 (RC72), p.1 . https://www.who.int/europe/publications/i/item/EUR-RC72-5

[138] World Health Organization (2024). Exploring the digital health landscape in the WHO European Region: digital health country profiles. https://www.who.int/europe/publications/i/item/9789289060998

the start of the COVID pandemic[139]. Over 80% of EU countries have a digital health strategy with a strong priority on data access, reuse and information sharing, and now all members states have public funding available for digital health programmes (ibid.). Digital transformation is indeed seen as an essential part for the sustainability of health industrial ecosystems, which warrants the need for these concrete digital health strategies for its successful implementation[140]. At a supra national level, the EU has explicitly set targets on e-health and electronic health records, where all EU citizens should have access to their electronic health data under the digital public services section of its digital Decade Cardinal Points document[141] following its mention in the European Declaration on Digital Rights and Principles for the Digital decade.

There is a clear expectation of access to digital health services by EU citizens as well as a strong policy commitment both by the EU and by member states for a digital transformation of the health industrial ecosystem. The digital transition of the health industrial ecosystem relies both on the public policies, the digitalisation of health records, delivery and services (which in many EU countries is delivered by public actors), as well as the digital transformation of companies in the ecosystem, or digital innovations brought by startup companies**.**

This report illustrated that industrial stakeholders can only take advantage of basic and advanced digital technologies if health data and services, primarily managed by public organisations, are sufficiently digitalised.

The box below briefly summarises the policy led digital transformation of national health records and health services ongoing in the EU, which is an important aspect of the ongoing transformation.

Box 3: Policies and implementation on e-health records in the EU

The digitalisation of health services has been a priority in the European Commission, as it has launched a number of policy initiative to substantially advance it. These key policy initiatives include:

- **European eHealth Action Plan** first plan has been adopted in 2004, the latest plan published in 2012[142] aims to unlock innovation for a patient centric approach, foster cross border healthcare, and improve the market and legal conditions for eHealth products and services.
- **eHealth network** was established in 2011 to support the formal cooperation on the implementation of eHealth systems and their interoperability.
- **European Health Data Space** (EHDS)[143] was adopted by MEPs in the European parliament in 2024 in order to enable better access of citizens to their health data in an electronic format also from other EU countries and enable transfer of health data between health professionals between EU countries. The sharing of data will go beyond health records and include data on clinical trials, pathogens, genetic data, health claims and reimbursements etc.

[139] World Health Organization (2023). The ongoing journey to commitment and transformation: Digital health in the WHO European Regin 2023. https://cdn.who.int/media/docs/librariesprovider2/data-and-evidence/english-ddh-260823_7amcet.pdf?sfvrsn=4c674522_2&download=true

[140] World Health Organization (2023). The ongoing journey to commitment and transformation: Digital health in the WHO European Regin 2023. https://cdn.who.int/media/docs/librariesprovider2/data-and-evidence/english-ddh-260823_7amcet.pdf?sfvrsn=4c674522_2&download=true

[141] European Commission (2023). Digital Decade Cardinal Points. https://ec.europa.eu/newsroom/dae/redirection/document/98695

[142] European Commission. eHealth Action Plan 2012-2020, COM/2012/736 final. https://health.ec.europa.eu/publications/ehealth-action-plan-2012-2020_en

[143] European Parliament (2024). EU Health Data Space: more efficient treatments and life-saving research. https://www.europarl.europa.eu/news/en/press-room/20240419IPR20573/eu-health-data-space-more-efficient-treatments-and-life-saving-research#:~:text=Citizens%20will%20have%20access%20across%20the%20EU%20to,and%20for%20what%20purpose%20sensitive%20data%20are%20shared

- **European Health and Digital Executive Agency** (HaDEA) was created in 2021 to "achieve an ambitious and integrated approach to health and digital issues"[144] and is responsible for the implementation of a number of EU programmes (e.g. EU4Health, Digital Europe Programme and many more).

A majority of EU countries have now adopted a digital health strategy, and have a particular health information system strategy, but also legislation to have e-health records and have a system either nationally, regionally or through a patient portal[145]. Member states clearly make accessibility, the development of information systems and information sharing a high priority.

[144] COMMISSION IMPLEMENTING DECISION (EU) 2021/173 (2021). establishing the European Climate, Infrastructure and Environment Executive Agency, the European Health and Digital Executive Agency, the European Research Executive Agency, the European Innovation Council and SMEs Executive Agency, the European Research Council Executive Agency, and the European Education and Culture Executive Agency and repealing Implementing Decisions 2013/801/EU, 2013/771/EU, 2013/778/EU, 2013/779/EU, 2013/776/EU and 2013/770/EU, Official Journal of the European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/?toc=OJ%3AL%3A2021%3A050%3ATOC&uri=uriserv%3AOJ.L_.2021.050.01.0009.01.ENG

[145] World Health Organization (2023). The ongoing journey to commitment and transformation: Digital health in the WHO European Region 2023. https://cdn.who.int/media/docs/librariesprovider2/data-and-evidence/english-ddh-260823_7amcet.pdf?sfvrsn=4c674522_2&download=true

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Appendix B: Methodology

Startup data and venture capital data analysis

In order to identify startups and private equity and venture capital investment in healthcare, we have used the following tags: Biopharma, Medical Device, Pharmaceutical. The results have been reviewed and false positives eliminated.

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.

Code	NACE category	Sample
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	200
C33	Manufacture of medical and surgical equipment and orthopaedic appliances	100

CORDIS data analysis

Industrial Ecosystem	Euro SciVoc codes used
Healthcare	Health care services, vaccines, virology, mortality, infectious disease, immunisation, organ on a chip, public health, cancer, nanomedicine, surgery, alzheimer, drug discovery, disease, physiotherapy, Pharmaceutical, personalized medicine, eHealth, diabetes, allergy, radiology, parkinsons, stroke, surgical procedures, orthopaedics, fetal medicine, hematology, cardiovascular diseases, pharmacokinetics, toxicology, antibiotic resistance, bone, muscular, glaucoma

LinkedIn data analysis

Categories selected: Pharmaceuticals, Medical Devices

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

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