European Commission

Monitoring the twin transition of industrial ecosystems

HEALTH

Analytical report

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Executive summary

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

The health industrial ecosystem represents one of the biggest and fastest growing industries globally and it plays a fundamental role for both society and the economy. According to Eurostat National Accounts, it is consuming over 10% of GDP on average in the EU27 and the gross value added of the ecosystem in 2019 was around €1.2 bn, accounting for 9.5% of the total EU value added. The ecosystem employed 24.8 million people in 2018 directly and a continuous rise of employment is expected over next decade[1].

Technological trends related to the twin transition in the health industrial ecosystems have been analysed based on patent statistics and startup data. The results highlight that the USA is an absolute leader with the highest share of the world patent applications in healthcare in 2020, although its leadership has been continuously declining since 2013. The EU27 has managed to keep second position over the past years, but the gap with China has dangerously decreasing over the last ten years, resulting only 6.3% of difference by 2020. This trend reflects a potential threat to Europe's technological and economic sovereignty in the domain of healthcare technologies and services.

Key findings about the green transition

The healthcare industry was responsible for approximately **7.2% of total greenhouse gas emission of all the industrial ecosystems**, contributing to a large extent to global warming as shown by the analysis of Exiobase data. Majority of the emissions are caused by the healthcare supply chain through the production, transport and disposal of goods and services. The healthcare industry is **above average global resource consumer in terms of raw materials**, where **an upward trend** can be observed. Even though healthcare contributes increasingly to the damage caused to the natural ecosystem, it remains way below the global average in cross-industry comparison of this study in terms of ecotoxic emission, water and land use. **Waste is a major issue for this ecosystem**. The majority of waste produced (around 85%) is non-hazardous (i.e. paper, cardboard, and plastics, discarded food, metal, glass, textiles, and wood) and can be recycled and only 15% of waste from the health ecosystem is potentially infectious, toxic, radioactive, and/or capable of other environmental and health risks and shall be subject to a special treatment.

Regarding technological development to foster the green transition of the health ecosystem, the USA displays stronger specialisation than the EU27 or China, with leadership in ten out of fourteen green transition technologies. In smart grids and greenhouse gas capture technologies, USA inventors hold more than 80% of the global patents. The **EU27 holds the strongest position in recycling, waste management, air& water pollution reduction and sustainable energy storage.**

[1] European Commission, 2021 Annual Single Market Report Brussels, 5.5.2021 SWD(2021) 351 final

Environmental technology startups have been playing an increasingly important role in the health ecosystem. They focus on environmental sustainability and provide a clean, less polluting solution such as reduction of waste with sorting technologies or development of advanced and more environment friendly materials for healthcare technologies and applications. Considering green technologies, healthcare tech startups providing technological solutions in the area of advanced manufacturing represent the largest group of startups analysed in the data set, with around 3.1%.

The business survey conducted as part of the project about the green transition of the health ecosystem revealed the following insights:

- 30.5% of the respondents in the health ecosystem indicated that they have increased their investments dedicated to the green transition over the past five years.
- 27% of SMEs in the healthcare industrial ecosystem adopted resource efficiency technologies and related solutions. Resource efficiency has been also highlighted as the most transformative environmental measure for businesses by the majority of respondents.
- 20.4% of the respondents said that they took actions to reduce medical waste.
- 25% adopted clean production technologies.
- 18% of the respondents invested in renewable energy technologies over the past five years.

Regarding skills development, the analysis of online job advertisements shows that there were 2 058 390 job ads published in the healthcare industries in the year 2022. Within this total, 2% of the job ads had a requirement for a green transition related skill. Trends over time suggest a limited interest in green transition related skills. The health ecosystem must **make significantly more efforts towards raising the awareness of the importance of green skills** in order to remain competitive in the changing landscape of global healthcare and successfully support the green transition of the ecosystem.

Key findings about the digital transition

In the field of digital technologies in healthcare, the USA displays stronger specialisation than the EU27 and China, having more than 50% share of patents in all digital transition technologies. Although China is investing heavily in medical technologies innovation, the general patenting activities are still lower than in the EU27 and the USA. **Augmented and virtual reality, additive manufacturing and autonomous robotics are the technology areas of most inventive dynamics in the EU27**.

In recent years, **there has been a steady trend of growing number of startups across different digital application areas** and new players entering the health market, supported by excellent investment opportunities (especially in seed financing) and supportive regulatory framework. Unlike in many other ecosystems, the global economic slowdown caused by the Covid-19 pandemic has created only minimal negative impact for healthcare startups.

The results indicate a dominance of startups focussed on medical devices development, which often use different digital technologies in developing novel diagnostic and treatment devices. More than **52 % of tech startups in the healthcare ecosystem offer Internet of Things and Artificial Intelligence technology-based solutions**, followed by online platforms, cloud computing and big data. Interest in Artificial Intelligence based solution has been growing in 2015 and so did the investments in startups. AI can be applied in the healthcare ecosystem in several ways, it enables automation of a number of different tasks in healthcare by reducing the human error and is the focus of 26.3% of the startups in the ecosystem.

Following the results of the business survey on the digital transformation of the healthcare ecosystem, it was found:

- 33% of the survey respondents indicated that they had increased of their investments dedicated to digital technologies during the past five years.

- 31% of the respondents used cloud-based software and related cloud platform services.
- Internet of Things has un uptake of 20.4% among SMEs in the healthcare ecosystem.
- Robotics has been adopted by 17.3% of the respondents.
- 3.4% of the respondents adopted digital twins within the ecosystem.

Digital tech startups in healthcare have received a total of €18 bn private equity and venture capital funding since 2010. **The total investments in health tech firms, which operate at early technological development stages, have more than doubled since 2015** and reached a total volume of over €468 m in 2022. Furthermore, access to late-stage venture capital exhibited also a rapid increase after 2017, reaching a total volume of €1.8bn in 2022.

Regarding skills development, the analysis of online job advertisements shows that 26% of the job ads requested skills relevant for the digital transformation of the ecosystem in 2022 in the EU27. **Trends over time suggest a dynamically growing demand for digital skills.**

1. Introduction

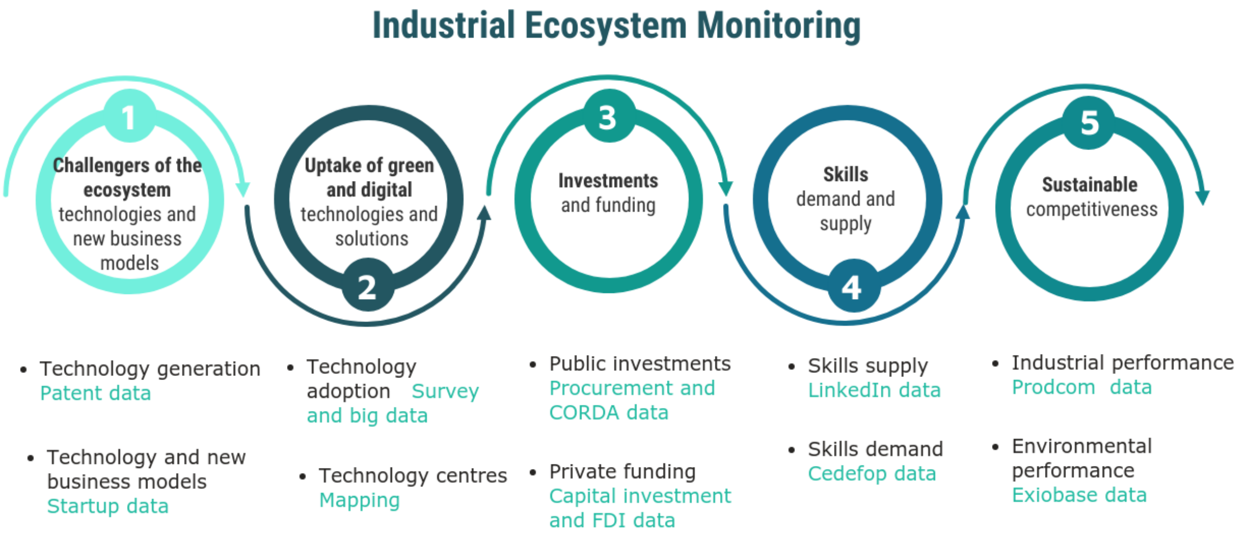
1.1 Objectives

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[2] has identified 14 industrial ecosystems[3] – 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 in particular by green and digital technologies and the shift to the circular economy. The process is however characterised by complex, multi-level, and dynamic development. To make transition sustainable, technological change needs to be coupled with new business models, the necessary investments, skills, regulatory framework conditions and behavioural change across the ecosystem.

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

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



Source: Technopolis Group, IDEA Consult and Fraunhofer ISI

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[2] 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

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

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

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

Figure 2: Main technologies monitored in the project

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

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

Source: Technopolis Group, IDEA Consult and Fraunhofer ISI

This report contributes to the analysis of the **key pillars put forward in the 'Blueprint for the development of transition pathways'**[4] of the Industrial Forum developed in 2022.

1.2 Definition of the ecosystem

There are vast variations among the definitions of health systems, mainly due to the different interpretation of boundaries. One of the most widely accepted and commonly used definitions is the one by the World Health Organization (WHO), according to which health system is comprising all the organisations, institutions and resources that are devoted to producing health action.[5] For the purpose of this study, we focus on a more elaborate definition of health *industrial* ecosystem, which comprises also different sectors included in the health ecosystems and it is outlined in the European Commission Annual Single Market Report 2021. Therefore, the scope of a health ecosystem (sometimes described also as healthcare or healthcare system) includes the following segments in this study: **manufacturing of pharmaceuticals and their key inputs, medical devices and equipment and personal protective equipment, healthcare services (medical and residential care), health technologies and related services**[6].

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

[5] WHO, 2000 The world health report 2000. Health systems: Improving performance. Geneva, Switzerland: WHO.

[6] European Commission, 2021 Annual Single Market Report Brussels, 5.5.2021 SWD(2021) 351 final

Therefore, health ecosystem in this report is an overarching term. It includes primarily patients and healthcare professionals together with all the different products and services involved in the inpatient or outpatient medical care, making it a very complex and broad system of various stakeholders along the value chain that are all dynamically interconnected via horizontal and vertical links among them, as well as framework conditions that support its functioning.

Being embedded in all the industrial ecosystems, it has direct effect on the quality of life of the European population. Digitalisation and green technologies are expected to transform the health ecosystems by introducing new learnings and insights, which will enable more effective patient healthcare across populations in a more sustainable way.

1.3 Industry state of play

The health industrial ecosystem represents one of the biggest and fastest growing industries globally and it plays a fundamental role for both society and the economy. According to Eurostat National Accounts, it is consuming over 10% of GDP on average in EU27 and the gross value added of the ecosystem in 2019 was around €1.2 bn, accounting for 9.5% of the total EU value added. The ecosystem employed 24.8 million people in 2018 directly and a continuous rise of employment is expected over next decade[7].

The health industrial ecosystem can be characterised by global and complex supply chains, dominated by large enterprises that have become global players. In parallel, there is also a huge number of new entrants from the technology, telecom and consumer industries, who can be considered the main origins of innovation in the health ecosystem. Considering the number of companies, the ecosystem is dominated by small and medium sized companies (SMEs), amounting to around 493 000 firms representing over 99.7% of all enterprises in the ecosystem. However, the upscaling of SMEs in the EU27 is seriously hindered due to unused synergies between large companies and SMEs. According to the Annual Single Market Report, the demand side of the health ecosystem is highly fragmented, making it very challenging for SMEs to access business opportunities, which in turn hinders its function of becoming an incubator of new innovative breakthroughs and contribute to economic growth in the EU[8].

Recently, both energy crisis and especially COVID-19 pandemic have affected all the industrial ecosystems either directly or indirectly. However, **no other ecosystem was affected by the pandemic as much as healthcare**, impacting various segments and exposing several vulnerabilities in health systems. For example, in health services delivery healthcare providers had to rapidly adapt to the changing environment, with many implementing new digital technologies, such as telemedicine and e-health applications to provide (remote) healthcare. Also, a number of other industry practices were proven not robust and resilient enough to face the pandemic, such as for instance sourcing or supply management around pharmaceuticals and medical devices. According to a recent report by the OECD, the pandemic transmitted a clear message to all the involved stakeholder of the ecosystem on the urgent need of establishing resilient and sustainable health systems[9], including improved data sharing and collaboration between healthcare providers as well as improved access to healthcare services, especially for more vulnerable populations.

Driven by the need for improved care outcomes and cost-effectiveness, the healthcare ecosystem is undergoing rapid transformations. Digitalisation is one of the current trends that is expected to make the health ecosystem more efficient and resilient by accelerating communication, enabling better accessibility of patient data while prioritising individual patient needs, enabling monitoring quality patient care and improving clinical support. Electronic health records (EHRs) are being used to store and share patient

[7] European Commission, 2021 Annual Single Market Report Brussels, 5.5.2021 SWD(2021) 351 final
[8] idem.
[9] OECD, 2023 Ready for the Next Crisis? Investing in Health System Resilience, OECD Health Policy Studies, OECD Publishing, Paris, https://doi.org/10.1787/1e53cf80-en.

data, while telemedicine can be applied to provide remote medical care. Data integration by latest technologies, such as blockchain, cloud and artificial intelligence (AI) and machine learning tools enable further advanced application of digital technologies in the healthcare ecosystem.[10] However, it also brings along a number of issues around protecting electronic health information and the need for greater cybersecurity.

In the EU, digitalisation is one of the top priorities and supported already by a number of different initiatives by the European Commission with a goal to establish the necessary framework for substantially advancing the digital transformation in healthcare. For example, the European eHealth Action Plan[11] is a strategy developed by the European Commission to boost the use of digital technologies in healthcare. It aims to improve the quality, safety, and efficiency of healthcare services across Europe. The associated **eHealth Network** is aimed at supporting the Action Plan and thereby establishing a link with the national level. Under the **e-Health Digital Services Infrastructure (eHDSI)** the European Commission has also adopted a recommendation on a **European Electronic Health Record Exchange Format (EHR-XF),** which is is a standard for exchanging electronic health records between healthcare providers across Europe, designed to ensure that patient data is secure and can be easily shared between healthcare providers[12]. **The European Health Data Space (EHDS)** is a health-specific data sharing framework to create a secure, interoperable, and open platform for sharing and using electronic health data across Europe by patients and also for reasearch, innovation, policy making or regulatory purposes. It is designed to enable access and share patient data in a secure and efficient manner[13]. The **European Health Data & Evidence Network (EHDEN),** is one of the flagship projects of the Innovative Medicines Initiative (IMI) , which is a network of healthcare providers, researchers, and other stakeholders that are working together to create a secure platform for sharing health data across Europe. The EHDEN Portal launched its first component, the Data Partner Catalogue in 2022[14]. Recently, at the beginning of 2023, the **EU and the US** have signed an **Administrative Arrangement on AI collaborative research**, which will help to identify and further develop promising AI solutions for a number of areas, including health and medicine[15].All these initiatives aim at improving the healthcare provision in the EU together with supporting the creation of necessary background structures for modern data-driven healthcare industrial ecosystem at all levels. A study in 2019 however indicated that despite by the EU level efforts, **EU Member States have been progressing at different speed in terms of digitalisation in healthcare** based on the Digital Health Index. Among the 13 EU countries included in the study, Estonia, Denmark and Spain were the best performing countries and ranked at the top of the list, while France, Germany and Poland were lagging behind[16].

Additionally, the growing concern over climate change and the need to reduce greenhouse gas (GHG) emissions and resource consumption, along with other environmental effects such as water and soil pollution or the loss of biodiversity, has made it necessary for many countries to take further steps towards more sustainable health systems. **The health ecosystem is struggling with new and exacerbated health problems (e.g. cardiovascular and infectious diseases) as consequences of global warming, being itself responsible for a significant amount of global GHG emission around 5**

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[10] Metty Paul, Leandros Maglaras, Mohamed Amine Ferrag, Iman Almomani, Digitization of healthcare sector: A study on privacy and security concerns, ICT Express, 2023, https://doi.org/10.1016/j.icte.2023.02.007.

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

[12] European Commission, Exchange of electronic health records acrodd the EU, https://digital-strategy.ec.europa.eu/en/policies/electronic-health-records

[13] European Commission, EU Health: European Health Data Space (EHDS). https://ec.europa.eu/commission/presscorner/detail/en/qanda_22_2712

[14] EHDEN, EHDEN Database Catalogue, https://www.ehden.eu/ehden-portal/

[15] European Commission, The European Union and the United States of America strenghten cooperation on research in Artificial Intelligence and computing for the Public Good. https://digital-strategy.ec.europa.eu/en/news/european-union-and-united-states-america-strengthen-cooperation-research-artificial-intelligence

[16] Bertelsmann Stiftung (2019) International comparision of digital strategies. https://www.bertelsmann-stiftung.de/en/publications/publication/did/summary-smarthealthsystems-focus-europe

%[17] and a major consumer of resources[18]. The United Nations Framework Convention on Climate Change also recognises that human health and the health of the plant are inextricably linked, i.e. the concept of Planetary Health and is calling for evidence-based policies that promote human health, while preserving the environment[19].

Broadly speaking, there are two main approaches to make the healthcare ecosystem more sustainable. First, **reduction of GHG emissions (i.e. in energy, products and services of the healthcare sector) and second resource efficiency, including waste reduction, recycling and management.** This has been already well acknowledged by the policy makers and Europe has witnessed first steps towards green transition in health ecosystem with the aim of shifting towards a more sustainable and low-carbon health system, contributing to the ambitious European Union (EU) overarching cross-sectoral targets to reduce GHG emissions by 55% of the 1990 levels by 2030 and achieve climate neutrality by 2050[20]. To achieve these targets, the EU has developed various policy frameworks to support the transition to a low-carbon economy, including the European Green Deal[21], which tackles all the climate and environmental-related challenges, the Proposal for the 8th Environment Action Programme to 2030[22] with a focus on strengthening the links between environment and health policies. Furthermore, as a response to the COVID-19 pandemic, the EU4Health programme was adopted by Regulation (EU) 2021/522[23], which among others also tackles the interplay of topics such as sustainability, climate change and health care. Also, the European Commission is currently setting up a European Health Union[24] to, among other objectives, further fight climate change and look for more sustainable patterns of economic growth in the health care sector.

However, unlike the majority of industrial ecosystems, healthcare is the most essential service to the society. Therefore, as highlighted in a 2017 strategic document[25] on the environmental sustainability of health systems from the World Health Organization (WHO) Regional Office for Europe, **no compromises can be tolerated between environmental sustainability and the performance of the health system**, i.e. lower quality of patient care the short term in order to improve their sustainability performance in the long term. Therefore, the **unique and essential challenge** in transforming health ecosystems towards higher digitalisation and sustainability is to **find the optimal balance between utilising the benefits of digital health while safeguarding data and infrastructures in ecologically sustainable healthcare ecosystems.**

Lately, the COVID-19 pandemic, which can be considered the greatest health crisis of a century, in addition to the energy- and subsequent economic crisis, exposed a range of pre-existing structural challenges in the health ecosystem that had a strong impact on the resilience. Based to the WHO definition[26] resilience in the healthcare system is the ability to prepare for, manage (absorb, adapt and transform) and learn from shocks, as an ecosystem.

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[17]Health Care Without Harm, 2019 Health Care's Climate Footprint, https://noharm-uscanada.org/ClimateFootprintReport

[18] e.g. 5 % of the total German raw material consumption is directly or indirectly attributable to healthcare services. See more: https://www.umweltbundesamt.de/sites/default/files/medien/5750/publikationen/2021-01-25_texte_15-2021_ressourcenschonung_gesundheitssektor.pdf

[19] United Nations Climate Change. Planetary Health, https://unfccc.int/climate-action/un-global-climate-action-awards/planetary-health

[20] European Commission, 2030 Climate Target Plan, https://climate.ec.europa.eu/eu-action/€opean-green-deal/2030-climate-target-plan_en

[21] European Commission, A European Green deal, https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/€opean-green-deal_en

[22]Eur-Lex, Document 32022D0591, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32022D0591

[23]Eur-Lex, Document 32021R052, https://eur-lex.Europa.eu/legalcontent/EN/TXT/?uri=uriserv:OJ.L_.2021.107.01.0001.01.ENG

[24]European Commission, https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/promoting-our-european-way-life/european-health-union_en

[25] OECD, 2017 Environmentally sustainable health systems: a strategic document, https://apps.who.int/iris/bitstream/handle/10665/340375/WHO-EURO-2017-2241-41996-57723-eng.pdf?sequence=3

[26] WHO, 2020. Strengthening Health Systems Resilience, https://apps.who.int/iris/rest/bitstreams/1282154/retrieve

According to recent data published by the OECD[27] and WHO[28], **the key areas to improve the resilience of health sector include: 1) financing and investments, 2) human and physical resources; 3) governance and co-ordination, 4) health services and care delivery.**

The OECD recommends an annual targeted investment of 1.4% of GDP across OECD countries relative to expenditure in 2019, on health workforce, prevention and key infrastructure. Also, higher preparedness of health systems is necessary, as less than 3% of total health expenditure is spent on prevention, leaving a large part of population in a very vulnerable state during external shocks and pandemics. Improvement of human capital, as a sufficient and well-trained workforce (including digital and green skills) is necessary to promote agility during crisis, as well as to address the care backlog. Furthermore, improvements in health data governance frameworks are necessary, to preserve trust of populations in how their health data is collected, stored, and used. However, increasing the reliance of health systems on digitalisation brings along in parallel risks related to cyber threats that need to be mitigated. Therefore, to strengthen the ecosystem's resilience, updated governance frameworks, ensuring interoperability and enhancing the use of existing data are important to building more resilience into health systems. Policies should both foster the development of data and AI-driven tools and sharing of these innovations equitably across the health system.[29] It is of crucial importance to ensure that health ecosystems can withstand current and future challenges and give people better access to the health services that they need.[30]

[27]OECD, 2023. Ready for the next crisis? Investing in Health Systems Resilience. https://www.oecd-ilibrary.org/docserver/1e53cf80-en.pdf?expires=1681305324&id=id&accname=ocid49022016&checksum=E81B759F6804DCCBD34DFD77C2B4681B

[28] WHO, 2020. Strengthening Health Systems Resilience, https://apps.who.int/iris/rest/bitstreams/1282154/retrieve

[29] Garcia-Perez et al 2023. Resilience in Healthcare Systems: Cyber Security and Digital Transformation, Technovation volume 121, https://www.sciencedirect.com/science/article/pii/S0166497222001304

[30] OECD, 2023. Ready for the next crisis? Investing in Health Systems Resilience. https://www.oecd-ilibrary.org/docserver/1e53cf80-en.pdf?expires=1681305324&id=id&accname=ocid49022016&checksum=E81B759F6804DCCBD34DFD77C2B4681B

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

Key findings

New digital and green technologies represent crucial enablers of the required transition in the healthcare ecosystem as a response to growing concerns about the effectiveness of healthcare and its impact on the environment. However, in healthcare, unlike other industrial ecosystems its primary function, providing care cannot be altered substantially in the light of potential negative environmental impacts[31].

Technological trends related to the twin transition in the health industrial ecosystems have been analysed based on patent statistics and startup data. The results highlight that the **USA is an absolute leader with the highest share of the world patent applications in healthcare in 2020,** although its leadership has been continuously declining since 2013. The **EU27 has managed to keep second position** over the past years, but **the gap with China has dangerously decreasing**, resulting only 6.3% of difference by 2020. As medical treatments based on living cells (unlike pharmaceuticals) in the EU are not subject to patent protection, according to the European Patent Convention, it can further support the trend in the EU27 compared to China, which is not a member of the Convention. This trend reflects a potential threat to Europe's technological sovereignty.

The US health ecosystems also displays stronger specialisation than its European and Chinese counterparts, having **more than 50% share of patents in all digital transition technologies** and ten out of fourteen green technologies. Furthermore, in **smart grids and GHG capture technologies**, USA inventors hold more than **80% of the global patents**. Although China is investing heavily in medical technologies innovation, the general patenting activities are still lower than in the EU27 and the USA.

The **European healthcare ecosystem does not display a very characteristic profile** in digital and green technology related patent applications and remains between the USA and China across all technologies. **Augmented and virtual reality, additive manufacturing and autonomous robotics are the technology areas of most inventive dynamics in the EU27**.

In green transition, **EU27 holds the strongest position in green technologies**, followed by **recycling, waste management, air& water pollution reduction** and **sustainable energy storage**.

In recent years, there has been a steady trend of growing number of startups **across different digital application areas and new players entering the health market, supported by excellent investment opportunities (especially in seed financing) and supportive regulatory framework.** Unlike in many other ecosystems, the global economic slowdown caused by the **Covid-19 pandemic has created only minimal negative impact** for healthcare startups.

The results indicate a dominance of startups focussed on **medical devices development**, which often use different digital technologies in developing novel diagnostic and treatment devices. More than 52 % of tech startups in the healthcare ecosystem offer **IoT and AI-based solutions**, followed closely by **online platforms, cloud computing and big data**.

[31] https://www.nature.com/articles/s41893-022-00951-3

2.1. Digital and green transition related technology developments in the health ecosystem

Maintaining sustainable health ecosystems is imperative for society. Generally, the shift towards more digital and green solutions in healthcare can be understood as a response to **growing concerns about the efficiency of the health ecosystem, its impact on the environment and the need to leverage technological advances to make the ecosystem more sustainable**. New digital and green technologies and solutions represent crucial enablers of the required transition in the healthcare ecosystem.

However, healthcare stands out compared to other industrial ecosystems, **as its primary function i.e. providing care, cannot be decreased nor altered in the light of potential negative environmental impacts**[32]. Therefore, if environmental targets are to be met, the healthcare ecosystem must undergo significant changes without sacrificing the quality of healthcare provision.

Digital transition in the health industrial ecosystem is driven by the vital need to improve the efficiency of the healthcare industry and to make it more resilient. Technologies, such as **on-demand healthcare, AI and big data, are critical in facilitating and optimising how healthcare is delivered**. AI enables to analyse patient data, detect patterns, and improve general clinical decision-making. AI data can also contribute to the R&D activities, such as genomics, precision medicine, drug development, or medical imaging. Big data will enable a shift from the current curative 'react' approach to a 'prevent' one in healthcare by providing technologies to detect risk factors and disease early, reduce the rate of medical errors, improve person power planning, reduce waiting times[33]. Block chain technologies can facilitate the transfer of medical records and data between different service providers and reduce costs. Virtual reality is a technology with a high added value by enabling healthcare professionals to practice their surgical skills, but also treat pain and several mental health issues of patients[34,35].

The **increasing use of telemedicine and other online healthcare services** is a major trend of the ecosystem, which since COVID-19 have become a key tool in providing remote healthcare services. Different related digital technologies, such as online platforms, electronic health records, remote patient monitoring, portable connected diagnostic and medical devices could radically change the way patients interact with healthcare professionals and how healthcare is delivered, making processes more streamlined, reducing costs and enabling patients to take better informed decisions on their health.

Furthermore, disruptive solutions are also expected to come in the future from the **merging different digital and biological technologies, bio-digital convergence**, which would create new technologies and applications in healthcare. This includes the use of digital techniques to synthesise various biological components, as well as the use of digital technology to control and manipulate these biological systems in real time[36].

Regardless of the consensus that digitalisation benefits all the involved stakeholders - ranging from patients and medical professionals to hospitals and health insurance companies - **cybersecurity is an emerging trend closely related to digitalisation that cannot be neglected.** There are constantly growing security risks, as more patient data is being collected and transferred electronically. It includes a number of different aspects beyond the protection from and prevention of cyberattacks, including for example

[32] https://www.nature.com/articles/s41893-022-00951-3
[33] WIPO, 2019, Global Innovation Index (GII) 2019 https://www.globalinnovationindex.org/gii-blog/2019/are-we-about-to-enter-a-new-%E2%80%9Cgolden-age%E2%80%9D-of-medical-innovation--b177
[34] APACMed, 2022, Digitizing Healthcare: Understanding the Key Trends, benefits and Challenges of Digital Health, https://apacmed.org/digitizing-healthcare/
[35] European Commission, 2019, Assessing the Impact of Digital Transformation of Health Services, https://health.ec.europa.eu/system/files/2019-11/022_digitaltransformation_en_0.pdf
[36] International Electrotechnical Commission, 2023, Understanding bio-digital convergence, https://etech.iec.ch/issue/2023-01/understanding-bio-digital-convergence

the constant availability of medical services, data confidentiality and the integrity of sensitive patient data. Therefore - digital healthcare is not conceivable without information security.[37]

Green transition in the healthcare industrial ecosystem is driven by the vital need to reduce the environmental impact of the industry by improving resource efficiency, reducing emissions, decreasing and recycling more efficiently (medical)waste, while exploring innovations such as advanced materials, electric transportation, 0-emission hospitals to improve the environmental impact of healthcare. This is apparent from the use of a number of green technologies, such as green pharmaceuticals, recycling technologies, energy saving technologies and renewable energy technologies: **recent trends and solutions for green healthcare include advancements in the reduction of energy-related CO2 emission and using resource-saving materials, sustainable catering for patients, the substitution of toxic chemicals, the safety of medicines, improved mobility strategies and the purchase of sustainable products in general** [38].

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

To track technological developments with relevance for the ecosystem and its green and digital transformation, we analysed **patenting activities related to the specific sectoral activities adopting patent-based classifications**. Our analysis was 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 were defined based on search that refer to patent classifications (IPC) and/or use keywords to identify relevant applications across classes. A detailed description of the methodological approach is presented in the EMI methodological report.

The Figure below shows the main trend in the EU27 share of world patent applications in the ecosystem. **The graph illustrates a general decrease in the share of patent applications by the European and the US healthcare industrial ecosystems in all worldwide patent applications in this domain.** Even though, according to the EPO analysis, innovation in healthcare drove patenting activity in Europe and was the leading field for inventions in terms of volume[39]. While in 2011 close to 30% of all patents in the ecosystem came from the EU27 countries and only a small share from China, this ratio has been significantly changing due to the significant technological catch-up of Chinese (and a smaller extent South Korea) companies. This resulted in **active patenting activities, increasing the market share in ten years from 5% to 15% by 2023 of the Chinese companies**.

This trend can be explained by the following factors. First, terminology can play an important role on IP in the health ecosystem, as medical treatments based on **living cells (unlike pharmaceuticals) in Europe are not subject to patent protection, according to the European Patent Convention**[40]. Therefore, in EU27 as well as all the other countries, who have joined the European Patent Convention, it is prohibited to patent methods of medical treatments, which can explain the trend of decreased patenting in the EU27 compared to China, which is not a member of the Convention.

Secondly, majority of patents in the health ecosystem are based on products on innovations, which require clinical trials in preceding step. According to clinical trials

[37] German Federal Office of Information Security, https://www.bsi.bund.de/EN/Themen/Unternehmen-und-Organisationen/Standards-und-Zertifizierung/E-Health/e-health.html

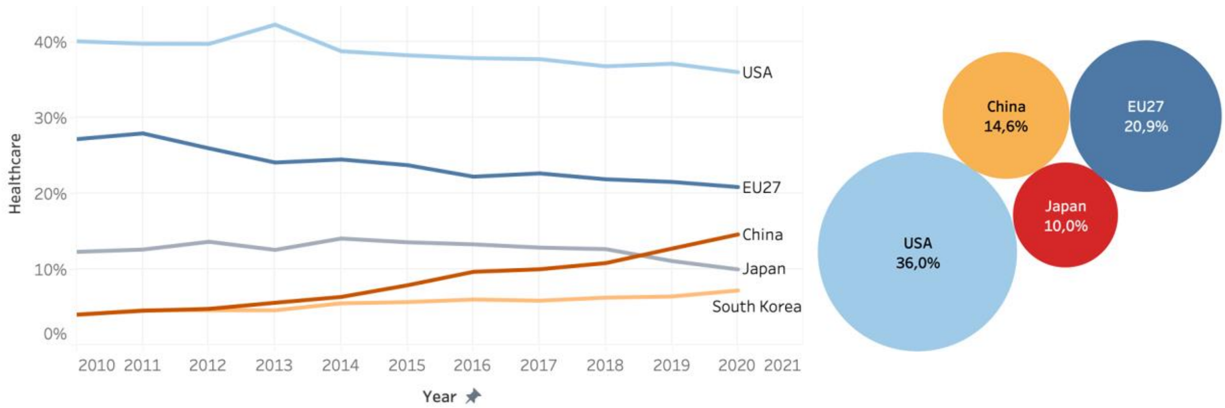
[38] Health Care Without Harm, 2019, Health Care's Climate Footprint, https://noharm-uscanada.org/ClimateFootprintReport

[39] EPO, 16.03.2021, Healthcare innovation main driver of European patent applications in 2020. https://www.epo.org/news-events/news/2021/20210316.html

[40] European Patent Convention, Article 53(c). https://www.epo.org/law-practice/legal-texts/html/epc/2020/e/ar53.html.

analysis by the WHO Health Observatory data[41], China has had a significant increase also in clinical trials over the last decade, which has therefore obviously resulted in higher patenting activities. **China also has a very patenting supporting climate, as direct financial subsidies (in addition to tax breaks and other social benefits) are provided to the patent applicants.** This is not healthcare specific but has definitely encouraged companies in the healthcare industries to invest in R&D and to file for patents that protect their intellectual property[42]. Also, in general China has a high demand for innovative medical solutions of growing population, which has created opportunities for companies to develop and deploy new technologies that can improve healthcare services. For example, China has had a sharp growth in patent applications for artificial intelligence (AI) in health ecosystem, which is the result of a very strong medical technology innovation push in China, according to the Global Innovation Index[43].

Figure 3: Trends in the EU27 share of patent applications in world total in the field of the Healthcare industrial ecosystem in 2010-2020 and global comparison in 2020



Source: Fraunhofer calculations, Patstat

We further conducted a more detailed analysis with a particular focus on digital and green transition. In this process, **our analysis of digital and green patent applications related to the ecosystem that was based on the 2022 PATSTAT database and exclusively focused on WIPO applications.** Both the industrial ecosystem and specific technologies were delineated by a set of Cooperative Patent Classification (CPC) categories. By using this approach, we were able to capture representatively the patenting activity in the entire ecosystem and observe trends in distribution and development with a view to specific technologies. The classification of green transition technologies builds upon the OECD green patents classification that we augmented by including additional technologies particularly relevant to the ecosystems. The identification of digital transition technologies builds on earlier work on Industry 4.0 (Balland and Boschma 2021) and includes additional technologies particularly relevant to the ecosystem.

Building on this, Figure 4 shows the development in the number of patent applications within healthcare that have either a digital or green technology involved over the years from 2010 onwards. **With respect to digital technologies, which are characterised by a wide implementation scope[44], there is a continuously growing trend in patent applications until 2019, followed by a decrease thereafter**. On the contrary, while there was an increasing trend in healthcare patent applications of green transition relevant technologies until 2017, it was followed by a slowdown from 2017 onwards. Additionally,

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[41] WHO Obervatory, https://www.who.int/observatories/global-observatory-on-health-research-and-development/monitoring/number-of-clinical-trials-by-year-country-who-region-and-income-group-mar-2020

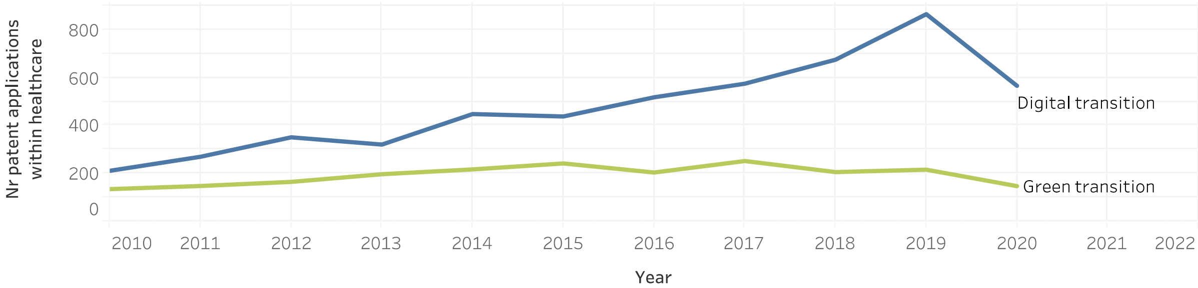
[42] United States Patent and Trademark office, 2021, Trademarks and patents in china: the impact of non-market factors on filing trends and IP systems. https://www.uspto.gov/sites/default/files/documents/USPTO-TrademarkPatentsInChina.pdf

[43] Science Business, 30.07.2019, Healthcare-related artificial intelligence patent applications surge in China. https://sciencebusiness.net/news-byte/healthcare-related-artificial-intelligence-patent-applications-surge-china

[44] German Patent and Trade Mark Office, 09.03.2022. https://www.dpma.de/english/services/public_relations/press_releases/20220309.html

the analysis shows a **decline in development of both considered technology groups after 2019, which can in part be explained by Covid-19 pandemic** and its generally negative effect on innovation in many segments including also healthcare. The pandemic led to a shift in priorities and focus, with many companies placing greater emphasis on short-term solutions to address the immediate challenges presented by the pandemic, such as ensuring the safety of their employees and customers and maintaining their financial stability, rather than longer-term research and development activities[45]. This shift in priorities, coupled with the economic uncertainty and financial pressures caused by the pandemic, has exacerbated a decrease in patenting activity in the entire ecosystem, as is evident also from other ecosystems, part of this report series (e.g. electronics, agri-food).

Figure 4: Trends over time in digital and green transition related patent applications connected to Healthcare industrial ecosystem



Source: Balland, 2022 based on PATSTAT

Zooming in on the specific technologies related to the green and digital transition, Figure 5 shows the distribution of patents by digital and green transition related technologies applied in the health industrial ecosystem. We analyse thereby the share of patent applications of EU27, China and USA in global total.

From Figure 5 we can see a strong dominance of the USA, followed by EU27 with two or three times less patents in each category. In general, the **US health ecosystems displays stronger specialisation in all the technologies related to the digital and green transition** than its European and Chinese counterparts, having more than 50% share of patents in all digital transition technologies and ten out of fourteen green transition technologies. The trend becomes particularly obvious in **GHG capture technologies**, where USA inventors have a very high dominance, and they hold more than 80% of the global patents. Also, facilitated by a strong research and development ecosystem for innovation in wide application areas of **smart grids** combined with a supportive legal and regulatory environment, the USA takes a very strong leading position (81.4%) in patent applications considering smart grids and closely related technologies. The situation is similar also in a number of other, both digital and green transition, technology fields, as illustrated in the table above.

[45] McKinsey, 2022, Covid-19 Implications for Business, https://www.mckinsey.com/capabilities/risk-and-resilience/our-insights/covid-19-implications-for-business

Figure 5: International comparison in digital and green technology related patenting in healthcare – share of the EU27, USA, China patent applications in healthcare within total EU-China-USA patent applications in the respective technologies and healthcare ecosystem (over the period 2017-2021)

Healthcare			
Technologies	**EU27**	**USA**	**China**
Digital transition			
Augmented and virtual reality	30,8%	57,7%	11,5%
Artificial intelligence	25,1%	64,0%	10,9%
Nanotechnology	25,5%	64,5%	10,0%
Additive manufacturing	34,3%	56,7%	9,0%
Internet of things	20,3%	67,8%	11,9%
Autonomous robots	30,3%	58,7%	10,9%
Cybersecurity	21,2%	68,8%	10,0%
Cloud computing	15,7%	69,0%	15,3%
Blockchain	18,9%	71,7%	9,4%
Quantum computers	26,7%	61,0%	12,4%
Smart grids	11,6%	81,4%	7,0%
Biotechnology	22,5%	64,8%	12,7%
Green transition			
Advanced Sustainable Materials	34,1%	52,9%	13,0%
Air & Water pollution reduction	39,3%	42,9%	17,8%
Batteries	20,9%	68,9%	10,2%
Waste management	37,0%	49,6%	13,4%
Solar energy	27,9%	59,7%	12,4%
Green buildings	35,0%	53,0%	12,0%
Recycling technologies	38,5%	53,8%	7,7%
Hydrogen	26,2%	68,9%	4,9%
Water related adaptation technolo	35,6%	57,8%	6,7%
Biofuels	24,4%	66,7%	8,9%
Other energy storage	41,2%	47,1%	11,8%
Greenhouse gas capture	18,8%	81,3%	0,0%
Legend			
	Low share		High share

Source: Balland, 2022 based on PATSTAT

Although **China** is investing heavily in medical technologies innovation and the total rate of patent applications have been steadily increasing since 2018, **the general patenting activities are still lower than in the EU27 and the USA** across all the analysed technology fields, related to green and digital transition in the healthcare ecosystem. With respect to the role of specific digital and green transition technologies for the healthcare ecosystem, Figure 6 illustrates as to be expected focus on cloud computing with more than 15% in China, followed by quantum computers by 12.4%. In green transition, in turn, China displays somewhat strongest specialisation, compared to digitalisation, holding almost 18% of global patents in air and water pollution reduction, followed by waste management (13.4%) and advanced sustainable materials (13%). In all the other technologies areas, Chinas patent shares are below 12%.

The **European health ecosystem** does not display a very characteristic profile in digital and green technology related patenting. Its **patenting levels remain second after US across all different technologies** in the analysed ecosystems. Furthermore, despite the substantial dynamism in EU27, the overall level of healthcare related patenting remains about two or even three times as low as in the US ecosystem, when considering globally relevant patents applied through the WIPO's PCT process. Nevertheless, augmented and virtual reality, additive manufacturing and autonomous robotics are the technology areas of inventive dynamics in the EU27, with more than 30% of global patents share with a view to **technologies related to digital transitions**, followed by artificial intelligence, nanotechnology, internet of things, cybersecurity, and quantum computers - all with a global market share between 20 and 30%. Regarding technologies related to **green transitions**, EU27 holds a relatively strong position in recycling, waste management, air& water pollution reduction and sustainable energy storage.

Thus, regardless of the active R&D scene, **European inventors continue to lag behind their US competitors in terms of patent applications on both digital and green healthcare technology development.** Compared to their Chinese competitors, EU27 is holding a leading position and has been submitting continuously two- or three-fold higher number of patents across all the different technology fields considered in the ecosystem. However, the trend is not in favour of the EU27, as the gap between China and EU27 is continuously decreasing.

2.2. Evolution of healthcare tech startups in the ecosystem

Health technology startups represent key building blocks in the transition towards a more digital, resilient and greener economic model in the healthcare ecosystem. Entrepreneurial activities help to accelerate the diffusion of novel (sustainable) patient-centric and disruptive healthcare solutions to traditional healthcare problems through the lens of digital technologies. and are also relevant indicators of how the industrial ecosystem is transforming itself towards digitalisation and reaching environmental sustainability objectives. **With increasing number of successful startups developing innovative diagnostic and treatment methods together with favourable regulation and available investment opportunities, increasingly more investors and entrepreneurs are interested in entering the European healthcare scene**. For example, in 2021, four European digital health startups (i.e. Kry[46], Alan[47], DocPlanner[48] and DentalMonitoring[49]) reached a valuation of USD 1 bn and the *unicorn* status[50].

In this section, trends in healthcare tech startups have been captured by analysing the Crunchbase database, which collects data primarily on venture capital-backed tech companies. Digital and green technologies have been linked to startups within healthcare and are described in the methodological report (the selected industry tags and technologies please see in Appendix B).

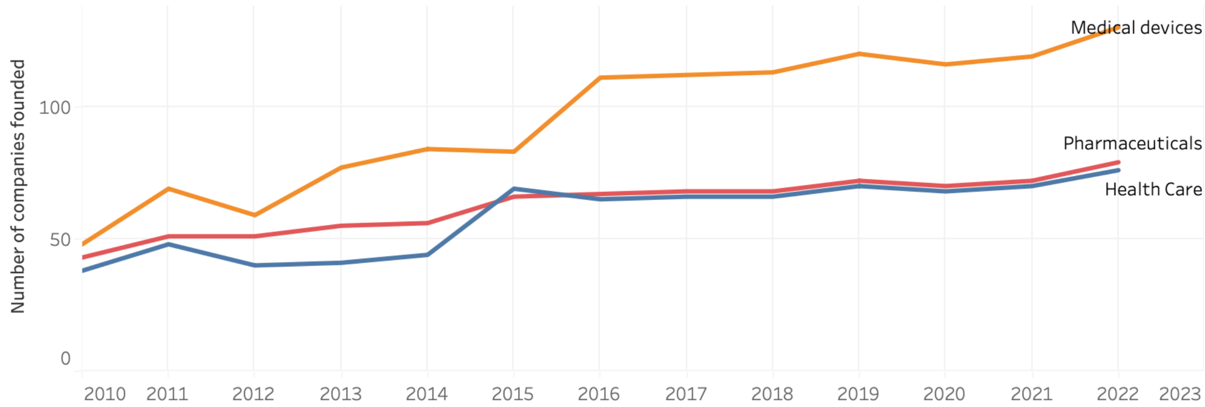
By investigating the evolution of healthcare companies in the ecosystem created over time, the first observation to make is a **stable and constant increase in the number of startups** with digital technologies, as core part of value proposition, i.e. business model, active within the industrial ecosystem over the analysed period from 2010 until 2022. This development indicates a progress towards the green and digital transition by **increasing share of new solution providers emerging** within the ecosystem and enabling the shift to a more digitalised, low carbon and circular economy model. **Digital tech startups** in the healthcare context include companies that address a particular challenge in the industry with the help of digital technologies (such as using Internet of Things to collect and connect medical devices and applications through online computer networks or offering health-related AI applications, which enable analysis of relationships between clinical techniques and patient outcomes). **Green technology startups** have a focus on environmental sustainability and provide a clean, less polluting solution such as reduction of waste with sorting technologies or development of advanced and more environment friendly materials for healthcare technologies and applications.

[46] www.kry.se
[47] www.alan.com
[48] www.docplanner.com
[49] www.dentalmonitoring.com
[50] Nicol-Schwarrz, K. (2022). Europe's digital health "soonicorns" https://sifted.eu/articles/digital-health-soonicorns

Growing demand for green and digital solutions, which results from increasing concerns about resilience of the healthcare system, pollution and climate change[51], represents a significant market opportunity for startups in the health ecosystem However, compared to digital technologies, the number of startups in the health industrial ecosystem that focus on green technologies is still low, despite the **strong technology push** policy characterised by e.g. generally **good availability of funding (especially since COVID-19 pandemic), as well as favourable regulatory environment**[52]. The main barriers in for the green technology startups can be associated with fundraising challenges, as the investors might prefer safer investments in a more established technology area with higher potential profits.

We zoomed in startups activities more specifically in the area of pharmaceuticals, medical devices and healthcare services and provision particularly. The results show a dominance of startups focussing on medical devices development for the health care industry, which have often advances in different digital technologies, such as AI, telemedicine etc. in developing novel diagnostic and treatment devices. Across all the areas a stable and **increasing trend can be observed with several new players entering the market to develop new medical devices, pharmaceuticals and provide more innovative digital and greener solution in health services in general.** Unlike in many other ecosystems, the global economic slowdown caused by the **COVID-19 pandemic has created only minimal negative impact** for healthcare startups and as Figure 6 illustrates, it has caused only a slight decline in new companies related to the healthcare startups between 2019 and 2020 (see Figure 6).

Figure 6: Trends in startups addressing pharmaceuticals, medical devices and health care innovation in the EU27



Source: Technopolis Group based on Crunchbase an Eurostat, 2022

We further analysed the core technologies for green and digital transition, which startups particularly rely their value proposition on the market, i.e. their business models, on. Figure 7 presents the statistics of the analysed technology groups, based on the analysis of the extracted Crunchbase data set of 2 879 active startups in the ecosystem founded between 2010 and 2022.

Interest in **Artificial Intelligence** based solution has been growing in 2015 and so did the investments in startups. AI can be applied in the healthcare ecosystem in several ways, it enables automation of a number of different tasks in healthcare by reducing the human error and is the focus of 26.3% of the startups in the ecosystem. It includes in the context of healthcare the following application areas: **medical imaging analysis**, where AI can be used to analyse medical images such as X-rays to assist with the detection and diagnosis of diseases such as cancer and heart disease. A Dutch company **ScreenPoint Medical**[53],

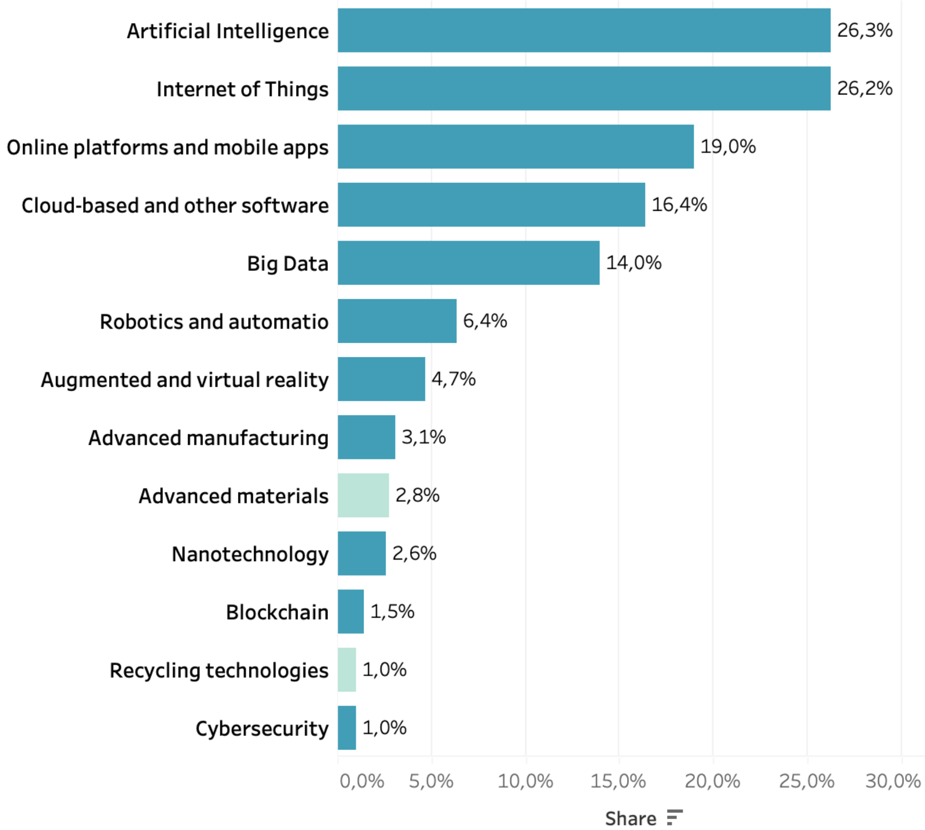
[51] Healthcare Industry BW, 2022, The Health Sector Must Become Greener, https://www.gesundheitsindustrie-bw.de/en/article/dossier/health-sector-must-become-greener

[52] European Commission, 17.12.2022, The European Innovation Council: over one and a half billion euro for breakthrough technologies, https://ec.europa.eu/commission/presscorner/detail/en/ip_22_7437

[53] https://screenpoint-medical.com/

has developed deep learning and image analysis technology for automated reading of mammograms. AI can also be applied in **interpretation of patient record data** or general health monitoring. For example, **Savana**[54] is a startup that reuses Electronic Health Records and extracts information using Natural Language Processing and Healz offers a software that measures and analyses the metabolism with AI through glucose monitoring and hormonal science. Both companies are based in Spain. AI can also be used in both **drug discovery and diagnostics**. For example, **Aspect Neuprofiles** develops machine-learning to improve diagnosis and management of autism and a German startup Aignostics[55] has developed AI-powered precision diagnostics focused on pathology to assist with drug development and clinical research.

Figure 7: Type of technologies and services within the healthcare tech startups in the EU



Source: Technopolis Group based on Crunchbase, 2022

With the increased connectivity across all sectors and areas of our life and the advent of 5G/6G communication/connectivity, technologies that underpin **Internet of Things (IoT)** represent a strong focus of 26.2% of the startups in the ecosystem. Many healthcare startups focus on remote patient monitoring, where devices can be used to remotely monitor patients sending data to the doctor. A large number of startups are developing devices for a wide range of different applications, such IoT-equipped sensors, as a Dutch company Momo Medical[56] who has developed a bed sensor that helps nurses track their elderly patients. Also, medicine monitoring, regarding the safe storage of drugs, vaccines, human tissue and lab samples, belongs to this category. As an example, a German startup KoolZone[57] offers real-time remote monitoring sensors for the pharma and healthcare

[54] https://savanamed.com
[55] https://www.aignostics.com/
[56] https://momomedical.com/
[57] https://koolzone.com/

industry. Many companies develop hardware design, software, and systems integration to go along with different products and applications within IoT.

Different **online platforms** are also the focus of the startups in the ecosystem, around 19%. Some examples include for example appointment scheduling platforms/and apps, which can be used to schedule appointments with healthcare providers. For example, the French startup and a biggest healthcare tech success case in Europe **Doctolib**[58] is an online and mobile booking platform that helps users find doctors and make appointments. Online platforms and mobile apps used to provide remote healthcare services, such as virtual consultations i.e. telemedicine. Besides DoctoLib, also a Spanish company Comtok connects healthcare professionals and patients and provides medical teleconsultations. These kind of platforms all are being increasingly accepted by the medical community and both public and private payers.

Cloud based and other software technologies are the focus of 16.4% of the startups for medical purposes process control and process optimisation in the emergency care. An example includes a cloud based EHR systems that can be used to store and manage patient health records securely.

Robotics and automation is significantly less prominent technology in the area, reaching just above 6.4%. The key application fields include surgery, where more accurate and less invasive surgery is enabled by the use of robotics. For example, the Dutch company **Microsure**[59], has developed a surgical robot for microsurgery with very high control and precision. Robotics can also be used to provide physical therapy and rehabilitation to patients. For instance, the Polish startup **Aether Biomedical**[60] is focused on building bionic limbs for upper limb amputees.

Augmented and virtual reality (AVR) is like robotics, a significantly less prominent technology in the area, reaching just above 4.7%. The key application fields include medical training, i.e. some startups are using augmented to simulate medical procedures and provide hands-on training to medical students and healthcare providers. For example, **VirtualiSurg**[61] is a French startup that designs and supplies simulators for virtual reality surgical training. Furthermore, there is an increasing trend using AVR is providing relaxation therapy, reducing the need for pain medications. The Belgium startup **Oncomfort**[62] has digital sedation method clinical hypnotherapy and integrative therapeutic techniques through VR. Startups provide virtual reality therapy for patients with physical or cognitive impairments, enabling them to practice and improve their skills in a virtual environment. For example, the Estonian startup **Virtual Rehab**[63] uses VR, AI, and block chain technologies for psychological rehabilitation.

Furthermore, all other sustainability relevant technology groups, for instance **advanced materials and recycling technologies**, are represented with as small shares of around 3.8% in total of all considered companies. Advanced materials in this context refers to synthetic or biological biomaterials that are engineered to be compatible with biological tissues (e.g. skin, muscles, bones) with different application areas. They enable a vast range of new opportunities to repair the human body. For example, **POLTISS**[64] is a Polish medical device company which develops technology of photo-cured, adhesive polymer biomaterials for soft tissue regeneration and **Cellink**[65] is a Swedish biotechnology company optimiser bench-top bioprinter for the ultimate bioprinting of human tissues. Regarding recycling technologies, entrepreneurial activity on medical and chemical waste

[58] https://doctolib.fr/
[59] https://microsure.com/
[60] https://www.aetherbiomedical.com/
[61] https://virtualisurg.com/
[62] https://www.oncomfort.com/en
[63] https://www.virtualrehab.co/
[64] https://poltiss.com/
[65] https://www.cellink.com/

management exists: the French startup **Tesalys**[66] has developed different advanced technologies to treat infectious medical waste at hospitals, laboratories and clinics.

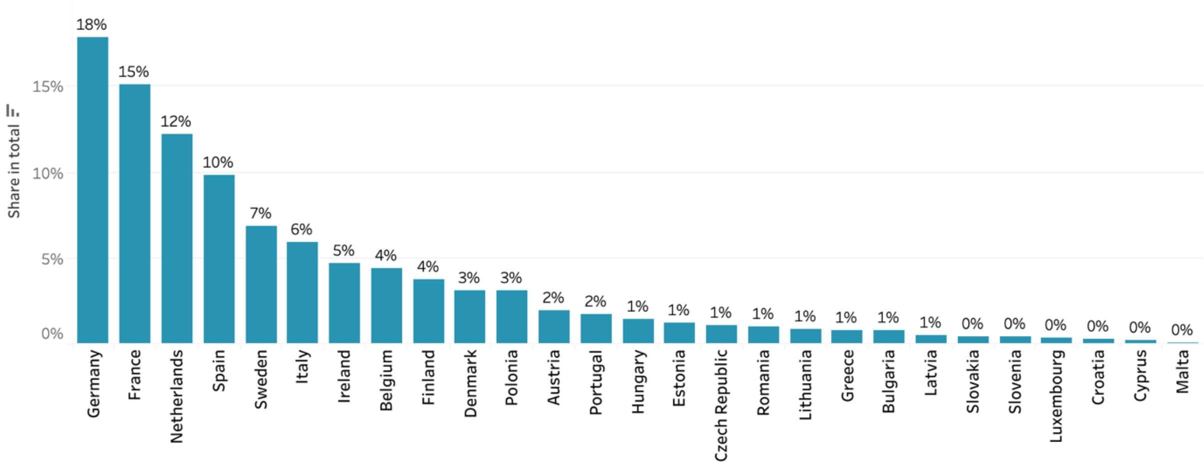
On the other hand, considering green technologies, companies providing technological solutions in the area of **advanced manufacturing** represent the largest group of startups analysed in the data set, with around 3.1%. Main trend 3D printing with different applications, like medical devices, where a French company **Lattice Medical**[67] offers a 3D printed bioabsorbable medical device for breast reconstruction. Personalised medicine also facilitated through 3D printing of drugs and organs. For example, the Bulgarian startup **Printivo**[68] develops bioprinted organs that can be tailored to patients' needs.

Blockchain and cybersecurity represent the smallest shares of digital technologies in this area (1.5 and 1% accordingly). Block chain is seen applied in the context of health data management in particular to securely store and manage patient health data, ensuring privacy and security. For example, **CareChain**[69] is Swedish venture that is developing several solutions to establish a blockchain infrastructure to improve health data management. Medical device cybersecurity focused startups, such as the company Irish company **Nova Leah**[70], which offers a risk assessment platform that guides medical device manufacturers through the process of identifying applicable vulnerabilities and identifying the right security controls to mitigate those risks.

Country insights

With the aim of exploring entrepreneurship trends in European countries, the number of startups in the industry ecosystem was analysed for the period between 2010 and 2020 based on Crunchbase data. The country distribution of startups is visualised in Figure 8. From the graph, we can see disparities across Europe. There are frontrunners such as Germany, France, the Netherlands and Spain, where around 55 % of all startups in the ecosystem are concentrated. This leading group is followed by Sweden (7 %) and Italy (6 %), as well as Ireland (5 %), Belgium and Finland (both 4 %). All other EU counties show rather lower statistics, with 4 % or lower shares of green and digital startups.

Figure 8: Share of number of Health startups per country



Source: Technopolis Group based on Crunchbase, 2023

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[66] https://www.tesalys.fr/en/
[67] https://www.lattice-medical.com/
[68] https://www.printivo.eu/
[69] https://carechain.io/
[70] https://www.novaleah.com/

3. Uptake of green and digital technologies and business models

Key findings

A business survey was conducted as part of the project about the status in the uptake of digital and green technologies and related business models in SMEs operating in the health ecosystem. The results reveal the following insights:

- 30.5% of the respondents indicated that they have increased their investments dedicated to the green transition over the past five years.
- 27% of SMEs in the healthcare industrial ecosystem adopted resource efficiency technologies and related solutions. Resource efficiency has been also highlighted as the most transformative environmental measure for businesses by most respondents.
- 20.4% took actions to reduce medical waste.
- 25% adopted clean production technologies.
- 18% of the respondents invested in renewable energy technologies over the past five years.
- The least cited green technologies include carbon capture.

Following the results of the business survey on the digital transformation of the healthcare ecosystem, it was found that:

- 33% of the survey respondents indicated that they had increased of their investments dedicated to digital technologies during the past five years.
- 31% of the respondents used cloud-based software and related cloud platform services.
- Internet of Things has un uptake of 20.4% among SMEs in the healthcare ecosystem.
- Robotics has been adopted by 17.3% of the respondents.
- 3.4% of the respondents adopted digital twins within the ecosystem.

With the objective to monitor the status in the uptake of digital and green technologies and related business models, this study adopted a mixed-method approach including a **business survey and text mining of company websites**. The survey was based on using Computer Assisted Telephone Interviewing (CATI). The final sample included 8 987 companies in all industrial ecosystems and 469 interviews for the health industrial ecosystem in particular. The mainstage fieldwork was conducted between 15 January and 31st May 2023. The survey respondents come from a mix of micro-enterprises (less than 10 employees), small enterprises (10-50 employees) and medium-sized enterprises (50-250 employees).

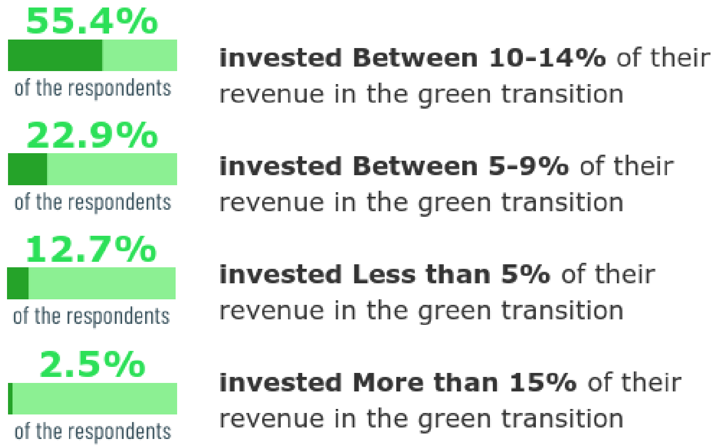
The results of other existing surveys have been also taken into account such as the Flash Eurobarometer 498 on SMEs, green markets and resource efficiency, and the ICT-usage in enterprises survey[71]. The different time of the field work for each survey can give some insights about progress even if the questions were not exactly the same. The Flash Eurobarometer 498's field work took place in November-December 2021. The last ICT usage survey results date from 2020.

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

3.1. Green transition of SMEs in health

As part of the EMI survey, respondents were asked whether they **had increased their investments dedicated to the green transition** and environmental sustainability during the past five years, and **30.5% of the respondents answered** positively, which is among the lower results of all fourteen industrial ecosystems. Similarly, the Flash Eurobarometer in 2021 found that **14% of the SMEs surveyed in the health ecosystem had a concrete strategy in place to reduce their carbon footprint and become climate neutral** or negative, and 8% was planning to prepare one.

Figure 9: Share of revenue invested in green transformation by SMEs in health industrial ecosystem on average annually



Source: Technopolis Group and Kapa Research, 2023

Nonetheless, a further question was related to the percentage in terms of the revenue that SMEs invested in green transformation on average annually. The responses show that more than half of the respondents (55%) **invested between 10-14% of their revenue** (see Figure above).

The detailed survey results demonstrate that SMEs in the ecosystem have been most active in the adoption of resource efficiency technologies, followed by clean production technologies. The EMI survey indicates that 27% of SMEs in the healthcare industrial ecosystem adopted resource efficiency technologies and related solutions. Resource efficiency has been highlighted as the most transformative environmental measure for businesses by the majority of respondents.

More specifically, **20.4% took actions to reduce medical waste**. As highlighted in the interviews, specifically healthcare SMEs applied several approaches to collect and dispose medical waste in a sustainable way.

Clean production technologies that help reduce the environmental impact in particular of the manufacturing activities of the ecosystem (pharmaceuticals) included solutions related to the reduction of energy consumption, waste generation, and pollution emission. The survey found that 25% of the respondents adopted such technologies.

The least cited green technologies include carbon capture (see Figure below).

Figure 10: Adoption of green technologies in the healthcare industrial ecosystem

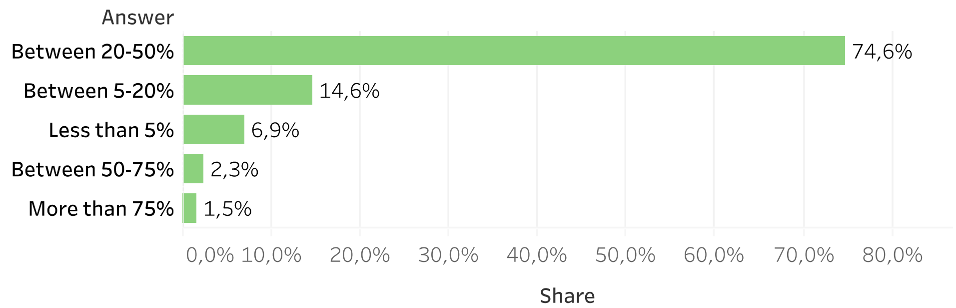
Green technologies	Answer: Already using	Answer: Planing to adopt
Resource-efficiency solutions	27,0%	0,2%
Clean production technologies	25,2%	0,7%
Recycling technologies	23,9%	0,5%
Renewable energies	23,7%	1,8%
Advanced sustainable materials (organic, bio-based, biodegradable)	23,0%	1,9%
Decentralised production technologies	21,4%	3,4%
Medical waste reduction technologies	20,4%	2,7%
Water reduction technologies	20,1%	0,7%
Electric vehicles (e.g. . zero-emission ambulances)	17,5%	2,3%
Carbon capture technologies	16,6%	3,5%

Source: Technopolis Group and Kapa Research, 2023

Renewable energy

The EMI survey found that **18% of the respondents invested in renewable energy technologies over the past five years** as displayed in Figure 11 at the beginning of this chapter. The results indicate that 37.5% of those that responded positively, cover less than 5% of their energy consumption by renewable energies with another 36% indicating a share between 20-50%. Solar energy has been one of the type of sources invested in directly for heating, cooling and lighting. There are however limitations since there are high upfront costs. The renewable energy share of the textiles industrial ecosystem is also monitored based on statistics from Eurostat. Although the last available year of this statistics is before the pandemic notably 2019, it demonstrates the evolution over time. The average EU27 renewable energy share was 45.2% (in 2019), while for the textiles industrial ecosystem it was much higher at 52%. This reflects a higher use of renewable sources.

Figure 11: Share of renewable energy use within total energy consumption by textiles companies surveyed in the EU27



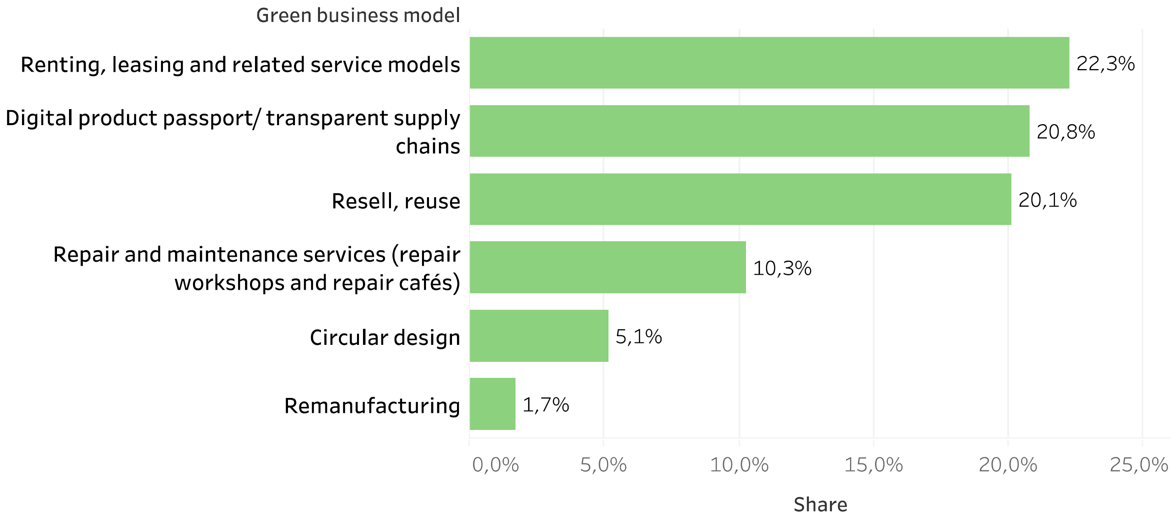
Source: Technopolis Group and Kapa Research, 2023

Circular business models and circular economy practices

Circular economy practices in the healthcare ecosystem include processes that aim to reduce environmental impact, minimise resource use, and recycle materials. The survey results show that **22.3% of the respondents adopted renting and leasing and related service models.** Leasing or renting medical equipment or products instead of selling them (eg. hospital beds, wheelchairs) is one of the most common circular practice. This approach allows creating a shared responsibility between the provider and the customer for the maintenance, repair, and disposal of the equipment or products.

Transparent supply chains have been highlighted also by a relatively high share of respondents, notably 20.8%. Reusing medical products or medical equipment has been applied by 20% of the respondents. This involves upgrading medical devices or components that would otherwise be discarded, such as MRI scanners, surgical instruments, or ventilators. This can extend the lifespan of the medical products, reduce the demand for new materials, and lower the costs.

Figure 12: Adoption of circular business models in the healthcare ecosystem in the EU27



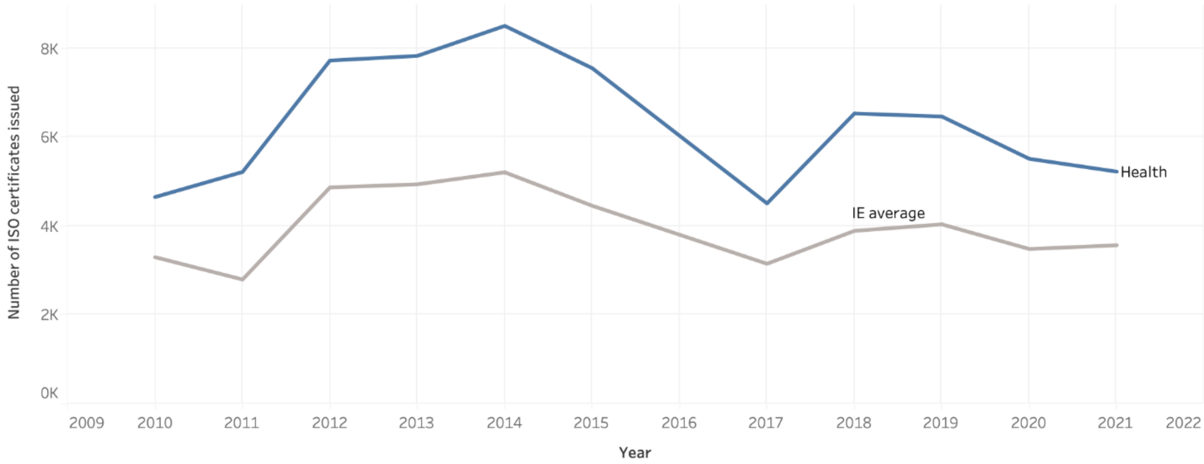
Source: Technopolis Group and Kapa Research, 2023

Environmental standards

When asked about the certification on any environmental standards, it is **only 19.5% of the respondents indicated that they had been certified** (see Figure 13) by a third party. There are a number of certificates and standards that aim to reduce energy consumption, improve energy efficiency, and promote sustainable energy practices in the textiles industry. Standards also play an important role as they can also help distinguish sustainable fashion from greenwashing.

The examples mentioned above show that stakeholders in the healthcare ecosystem have many possibilities to realise resource-saving production and/or their activities. Another helpful instrument for managing resource consumption are **certificates** and **standards.** There are a number of certificates and standards that aim to reduce energy consumption, improve energy efficiency, and promote sustainable energy practices. For instance, **ISO 14001** includes a set of standards that any company can follow to implement an effective environmental management system. By adopting the good practices suggested by the standard, firms can substantially reduce their environmental footprint. The number of environmental certificates issued in the industry indicates the progress towards the application of environmentally friendly business practices and production methods. For the purposes of this report, ISO data were accessed via the ISO survey of certifications to management system standards[72].

Figure 13: Number of environmental certificates issued in the healthcare sector.



Source: Technopolis Group, 2022, based on ISO

The healthcare ecosystem, while providing healthcare products and services to the public, is also influencing the environment in many ways, such as transportation, facilities construction, management and maintenance; energy and water use; antibiotic and hazardous chemicals use and waste, which all have an environmental footprint. The analysis of the data shows that companies and service providers operating in the health ecosystem obtained increasingly less ISO environmental certificates since reaching the peak in 2014. The number of certificates issued decreased steadily until 2017, with a rapid peak in 2018 and has thereafter continuously decreasing. The annual ISO survey indicates that there were more than 5 000 certificates issued to healthcare companies in the EU27 in the year 2021, which number is a decrease compared to more than 8 000 certificates issued in 2014. This data is in line with former studies that have already indicated a problematic uptake of environmental management systems by different stakeholders in the ecosystem[73].

The explanation for the decline in environmental certificates could be manyfold, ranging between different internal and external barriers. Lack of human and financial resources, needed **for acquiring ISO certificates can be one the key factors**. As the ISO140001 is a voluntary standard, there are no consequences for not adhering to these standards. Therefore, some device producers may choose to prioritise resource savings over environmental responsibility and not establish the certificate, as depending on a numerous factors (i.e. size of the company, national regulation etc.), ISO certification can be extremely costly[74]. Also, lack of understanding on how organisation exactly can benefit from the certificates, problems with implementation and negative attitude and culture can also play a role, combined with lack of necessary guidance and support on acquiring the certificates[75].

However, it is important to note that majority companies in the health ecosystem are law-abiding and follow environmental standards and certificates. Additionally, healthcare

[72] ISO, 2022. ISO Survey of certifications to management system standards. https://isotc.iso.org/livelink/livelink?func=ll&objId=18808772&objAction=browse&sort=name&viewType=1
[73] Seifert, C. 2018, The Barriers for Voluntary Environmental Management systems - the Case of EMAS in Hospitals. https://tud.qucosa.de/api/qucosa%3A30981/attachment/ATT-0/?L=1
[74] Marsh, ISO 14001: Analysis into its strengths and weaknesses, and where potential opportunities could be deployed for tomorrows Global Business , http://greenleansolutions.com/resources/ISO14001.pdf
[75] Seifert, C. 2018, The Barriers for Voluntary Environmental Management systems - the Case of EMAS in Hospitals. https://tud.qucosa.de/api/qucosa%3A30981/attachment/ATT-0/?L=1

companies often claim themselves to be committed to sustainability and actively work towards reducing their environmental impact (e.g. Philips Royal, Siemens). [76]

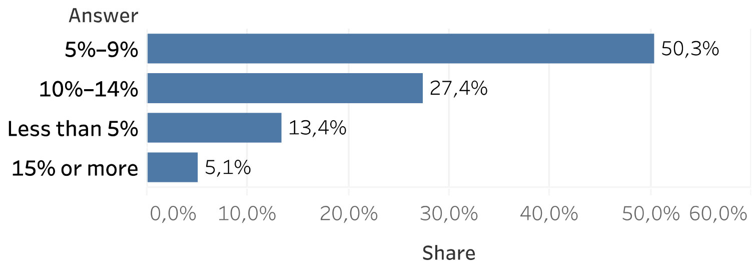
The overall worrisome decline in the number of **environmental certificates issued** should be monitored and analysed further, as these standards and certificates are important tools in promoting sustainable practices and reducing the environmental impact of the healthcare industry.

In order to address the declining number of environmental certificates, it's important to **prioritise sustainable practices** and support and educate the stakeholders on the benefits of implementing these practices. EU policy could also support firms by providing education materials and push public debates on that subject. Finally, consumers can also play a role by supporting companies that prioritise sustainability and rewarding those that make efforts to reduce their environmental impact. Policymakers could **strengthen consumer sovereignty** in this regard by giving consumers better and easier means to learn about the sustainability of companies.

3.2. Digital transition of SMEs in health

SMEs in the healthcare industrial ecosystem have been engaged in the digital transformation and **33% of the survey respondents indicated that they had increased of their investments dedicated to digital technologies during the past five years**. A further question was related to the percentage in terms of revenue that SMEs had invested in digital transformation on average annually. The responses show that half of the respondents notably **50% invested between 5-9% of their revenue** in digital technologies.

Figure 14: Share of revenue/income invested in digital transformation on average annually



Source: Technopolis Group and Kapa Research, 2023

The level of adoption of specific digital technologies relevant for the ecosystem is presented in Figure 15. Overall, cloud technologies have been adopted the most followed by the Internet of Things, robotics and big data.

[76] https://www.philips.com/a-w/about/environmental-social-governance/environmental/circular-economy.html and https://www.siemens-healthineers.com/company/sustainability

Figure 15: Adoption of digital technologies by SMEs in the healthcare industrial ecosystem following the EMI survey results

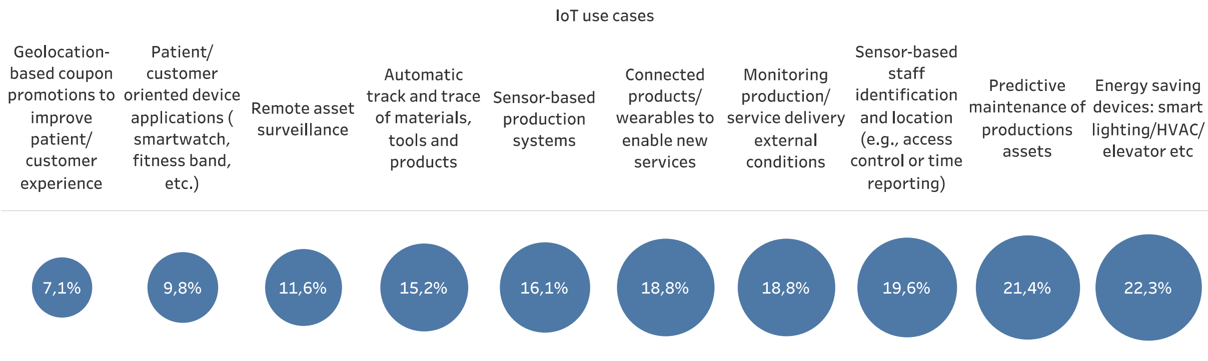
Digital technologies	Answer: Already using	Answer: Planing to adopt
Cloud technologies	31,0%	7,0%
Internet of Things	20,4%	4,0%
Robotics	17,3%	3,0%
Big Data	15,3%	3,0%
Artificial intelligence	13,7%	3,4%
Remote patient monitoring technologies	8,6%	1,0%
Decision support systems	7,5%	1,2%
Augmented and virtual reality	7,5%	4,5%
Blockchain	5,0%	0,5%
Digital twin	3,4%	2,0%

Source: Technopolis Group and Kapa Research, 2023

Cloud technologies in this project have been defined as the **use of cloud-based software and related cloud platform services. The results show that 31%** of the respondents in the EMI survey covering the health industrial ecosystem adopted these technologies. Cloud technologies in a broader definition (buying cloud services over the internet) had been adopted by 64.1% of the companies in the manufacturing of basic pharmaceutical products and pharmaceutical preparations in 2021 as revealed by Eurostat statistics[77].

Internet of Things has un uptake of 20.4% among SMEs in the healthcare ecosystem. IoT was applied most often with the objective to save energy and as part of energy-saving devices. It was also used for predictive maintenance of production assets.

Figure 16: Use cases of Internet of Things (share of companies within those that already use IoT)



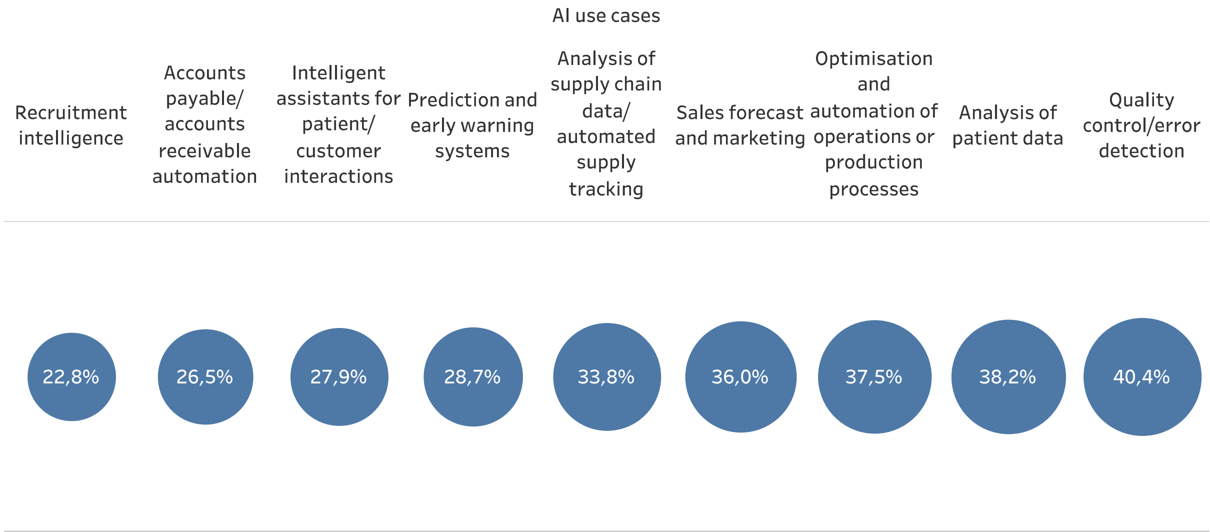
Source: Technopolis Group and Kapa Research, 2023

Big data and related data analytics have been adopted by **15.3% of the SMEs** in the ecosystem as found by the EMI survey. **Artificial Intelligence has an uptake of 13.7%** among SMEs in the ecosystem. The related indicator in Eurostat[78] that measures the use

[77] https://ec.europa.eu/eurostat/databrowser/view/ISOC_CICCE_USEN2__custom_7168583/default/table?lang=en
[78] https://ec.europa.eu/eurostat/databrowser/view/ISOC_EB_AIN2__custom_7168459/default/table?lang=en

of AI by enterprises by economic activity found that **15.9% of enterprises in manufacturing of basic pharmaceutical products and pharmaceutical preparations** adopted at least one Artificial Intelligence technologies in 2021.

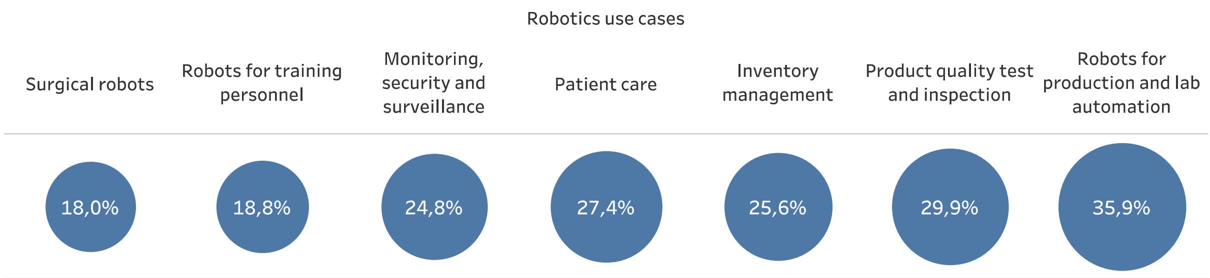
Figure 17: Use cases of AI among healthcare SMEs



Source: Technopolis Group and Kapa Research, 2023

Robotics has been adopted by 17.3% of the respondents. Available data by Eurostat[79] indicates that 17.2% of the enterprises in manufacturing of basic pharmaceutical products and pharmaceutical preparations used industrial or service robots in 2022.

Figure 18: Use cases of robotics – share of respondents that adopted robotics and use this technology for the indicated purpose



Source: Technopolis Group and Kapa Research, 2023

Digital twins create a virtual replica of a physical product, process or system and allow for real time analysis. The survey concluded that **3.4% of the respondents adopted this technology within the ecosystem**.

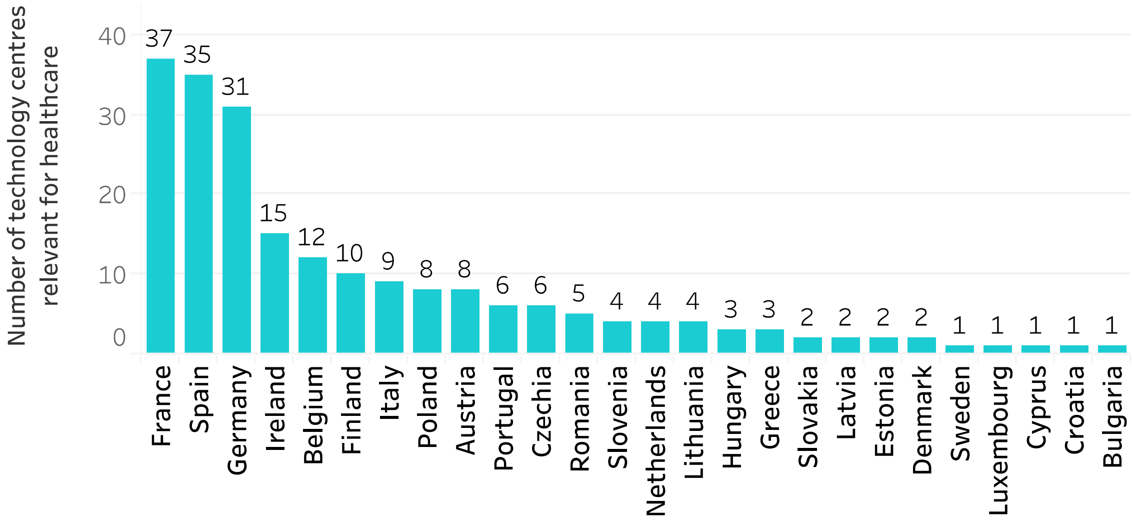
[79] https://ec.europa.eu/eurostat/databrowser/view/ISOC_EB_P3DN2__custom_7166607/default/table?lang=en

3.3. Technology centres supporting technology uptake

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

Figure 19 presents the number of technology centres that are active in the health industrial ecosystem per European country and shows that France is the country with the higher number of technology centres in Europe (37), followed by Spain (35) and Germany (31). The top five is further complemented by Ireland (15) and Belgium (12). These countries might host additional technology centres active in health, which are currently not registered to the technology centres mapping.

Figure 19: Number of technology centres that are active in the health industrial ecosystem per country



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

The following examples serve to illustrate the activities and scope of technology centres active in health industries, their links with the broader ecosystem as well as examples of recent activities in which they are involved. They include the following three cases: RCPE - Research Centre Pharmaceutical Engineering GmbH (AT), MET – Medical and Engineering Technologies (IR), and FTMC - Centre for Physical Sciences and Technology (LT).

Box 1: Example Technology Centre: RCPE - Research Centre Pharmaceutical Engineering GmbH (AT)

Name of the Centre	**RCPE - Research Centre Pharmaceutical Engineering GmbH (AT)**
Location and scope	
RCPE is a research centre based in Graz, Austria, founded in 2008. It is formed by 150 professionals from over 20 nationalities. RCPE is considered a COMET Centre (Competence Centre for Excellent Technologies Programme) funded by the Climate Action, Environment, Energy, Mobility, Innovation and Technology Department and the Labour and Economy Department of the Federal Ministry Republic of Austria, FFG, Land Steiermark and SFG.	

The main objective of RCPE is to provide its partners novel drugs and to offer safe and more affordable therapies to patients. The centre works through the whole process, from early stages to commercialisation. RCPE is part of the following networks, clusters, and initiatives: BioNanoNet, International Institute for Advanced Pharmaceutical Manufacturing, and European Consortium for Continuous Pharmaceutical Manufacturing, among others.
Main services and equipment
• **Research & Development** in innovative pharmaceutical products through four cross-functional areas: Modeling & Prediction, Advanced Products & Delivery, Process & Manufacturing Science and Continuous Flow Synthesis and Processing. • **Predictive tools** for high fidelity simulations, advanced material science, and biopharmaceutics. • **Quality control** through sensors, optical coherence tomography (OCT), and process control and soft sensors. To provide these services RCPE has over 1000 m² of laboratory and pilot plant for the development of new technologies for the pharmaceutical industry and a Centre for Continuous Flow Synthesis and Processing (CC FLOW).
Recent projects related to the green and digital transition in health industries
• **RCPE and InSilicoTrials to Digitalise and Accelerate the Development of Pharmaceutical Manufacturing Processes:** RCPE and InSilicoTrials have partnered to commercialise the XPS simulation software. This software for pharmaceutical applications, enables companies to evaluate their process configurations in detail and explore the decision space without time- and labor-intensive experiments. • **Phoenix** project: aims to facilitate the translation of nanopharmaceuticals from bench to bedside through the establishment of an open innovation test bed (OITB). Phoenix-OITB will consist of a network of facilities, technologies, services, and technology transfer expertise to produce and commercialise nanopharmaceuticals.

Source: Advanced Technologies for Industry Technology Centre Mapping, 2023 and RCPE, 2023 https://www.rcpe.at/

Box 2: Example Technology Centre: MET – Medical and Engineering Technologies (IR)

Name of the Centre	**MET – Medical and Engineering Technologies (IR)**
Location and scope	
MET is an Irish research centre founded in 2016. It provides services in MedTech, Life Sciences and Engineering within the Atlantic Technological University in Galway. The innovative solutions produced are addressed to companies of all sizes, from start-ups to SMEs and multinationals. MET is affiliated to Enterprise Ireland, the Centre for Applied Biomedical Engineering Research (CABER), GeorgiaTech, Metricireland, Engineers Ireland, Irish MedTech Association (Ibec) and the Health Innovation Hub, among other entities.	
Main services and equipment	
Within its service catalogue, MET offers:	

- **Research & Development** services, which include data repository services, anatomical modelling, access to equipment, technical writing, training, and teaching.
- **Technology Gateway Programme**: MET is part of 16 Technology Gateways network providing solutions to the market needs of the Irish industry.
- Material testing and simulation services.
- Data workflow modelling and visualisation services.
- **3D printing** for rapid prototyping
- Ultrasound
- Certification

In relation to the technologies, MET works with medical imaging technologies, technologies for anatomical modelling and physiological replication, data analytics and visualisation technologies, design engineering and verification and medical nutrition and sport technologies.

Recent projects related to the green and digital transition in health

- Innovation partnership with 4Tech Cardio Ltd, a medical device company working on the development of transcatheter technologies. The partnership served to accelerate its research and development models.
- The MET Gateway & Neuravi collaborated on an Enterprise Ireland Innovation Partnership project to address the technology gap of not having a cerebrovascular model commercially available by developing an in vitro simulation system.

Source: Advanced Technologies for Industry Technology Centre Mapping, 2023 and MET, 2023 https://metcentre.ie/

Box 3: Example Technology Centre: FTMC - Centre for Physical Sciences and Technology (LT)

Name of the Centre	**FTMC - Centre for Physical Sciences and Technology (LT)**

Location and scope

FTMC was founded in 2010 by the merger of the Vilnius Institute of Chemistry, Vilnius Institute of Physics and Semiconductor Physics and Kaunas Textile Institute.

The core research activities of FTMC are to carry out basic and applied research, and experimental research in the areas of health, physics, chemistry, and technologies, that are of great significance for government, society, and companies.

In the pursuit of innovative new devices and technologies, FTMC closely collaborates with colleagues from Germany, France, UK, Scotland, Poland, Taiwan, the USA, and various other countries, and conducts EU and bi-lateral collaborative research projects. FTMC is a full partner of a number of worldwide organisations: EPIC (European Photonics Industry Association), OSA (Optical Society of America) and LIA (Laser Institute of America).

Main services and equipment

- **4 accredited departments for quality control** on corrosion research, mass spectrometry research, studies of textile materials and metrology. These departments provide concrete services such as optical measurements and investigations, electromagnetic compatibility testing, magnetic validation, plasmonic drug testing, and optical coatings, among others.
- **Technology Transfer** services through the innovation and technology office, which supports the technology transfer from laboratories to the market. As a consequence, a number of spin-off companies have been developed.
- **Specialised trainings** for PhD studies and non- academic trainings in optoelectronics.

- **Networking services** as the FTMC is affiliated with science and technology parks focused on photonics, precision engineering and optoelectronics. It is also a member of the European Research Association for Research and Technology Organisations (EARTO).

Recent projects related to the green and digital transition in health industries

- **EDIAQI** project: Through this Horizon Europe project, 18 leading European organisations, including FTMC, unite their strengths to tackle and reduce the growing threats of indoor air pollution and to foster healthy working and living environments in Europe.
- **New generation lasers to fight cancer**: On 23 March 2023, the Extreme Light Infrastructure (ELI) workshop was held at FTMC. The event gathered laser technologies specialists from the Czech Republic, Hungary, France, Germany, Italy, Spain, and Lithuania. ELI is an internationally operating laboratory facility that uses high-power lasers. These lasers are expected to be useful in a wide range of fields: research, industry, and medicine, and more concretely, in the prevention of cancer.

Source: Advanced Technologies for Industry Technology Centre Mapping, 2023 and FTMC, 2023 https://www.ftmc.lt/

4. Investment and funding

Key findings

The EU27 healthcare ecosystem has attracted an increasing volume of private equity and venture capital investment over the last years, indicating a minimal negative effect of the COVID-19 pandemic to the innovation scene of the healthcare ecosystem.

Digitalisation of healthcare has been backed up particularly well by investments, as different digital technologies are increasingly underpinning almost all aspects of modern healthcare. Digital technology-based healthcare startups have received a total of €18 bn funding since 2010. The total investments in firms, which operate at early technological development stages, have more than doubled since 2015 and reached a total volume of over €468 m in 2022. Furthermore, access to late-stage venture capital exhibited also a rapid increase after 2017, reaching a total volume of €1.8bn in 2022.

Regarding core technology investments, the startups offering online platforms have gathered a total of €2 bn since 2010, one of the most successful examples is the French company DoctoLib, which boomed during the pandemic, by enabling access to vaccinations and consultations with relative ease. AI-driven and IoT companies have also seen a sharp increase in the availability of funding reaching a total of €563 m in 2021 which is more than four times their total funding in 2017. Companies using big data and analytics at the core of their business model have also seen their market growing in the last years. However, the main type of funding is still early VC. German company ATAI Life Sciences , focused on developing data driven approaches for mental health, has secured access to almost €500 m in less than 5 years. Robotics is also expected to have a far-reaching impact on many areas of the healthcare sector (i.e. surgeries, supply delivery, patient care), but the funding has remained somewhat lower compared to other above listed technology areas, reaching around €150 m in 2021.

Foreign direct investments of the EU27 healthcare ecosystem peaked in 2018 and declined until 2020. Since then, outwards EU27 foreign investments have been significantly below the level of the past ten years and despite a gradual improvement, have not recovered yet. The inside EU27 investments in the healthcare ecosystem have been continuing gradual increase since 2019, despite the pandemic.

According to data from the Community Research and Development Information Service (CORDIS), the programme funded 839 projects classified under healthcare with a total funding of €4.4 bn in 2014-2020. The digital transition related projects accounted for €1.1 bn and the green transition related project for €527 m within the total funding.

With regard to public procurement in the healthcare industry, the transition is led by green rather than digital procurement. Highest relative growth in numbers of notices, within the green transition, stems from waste reduction and management: recyclability and durability of medical devices, which are also the key sustainability challenges for the ecosystem.

4.1. Venture capital and private equity investments

Investment data has been captured from various sources including private equity investment, venture capital investment into new technologies, foreign direct investment and public procurement. The scale of venture capital and private equity investment in healthcare tech startups has been calculated using data from the Crunchbase database already presented above.

The analysis of Crunchbase allowed to capture investment information for funding rounds healthcare tech companies. The investment figures presented in this section refer only to the funding rounds where a value has been disclosed. Those investments for which no values were published are therefore not included in the analysis.

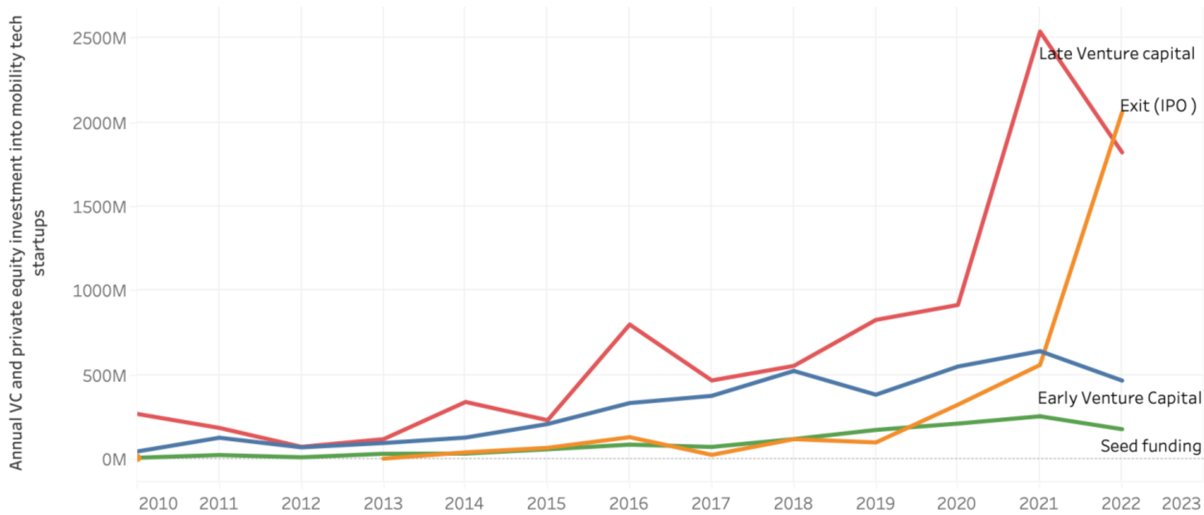
Overall, there has been an increase in funding over the course of the last ten years in Europe's healthcare industry. Healthcare startups have received a total of €18 bn funding since 2010. There has been, in general, a steady increase of private equity and venture capital investment since 2010. The VC and private equity funding is equally distributed between seed-stage and late stage funding.

Seed-stage and early venture capital has been steadily increasing with a 200% growth during the period 2015-2021, what points out to a higher availability of funding as well as to a growing financial interest in health startups.

Furthermore, access to late-stage venture capital exhibited a rapid increase after 2017, having more than tripled in 2022, reaching a total volume of €1.8 bn. This development indicates not only the rising interest in healthcare startups but also the consolidation and maturity of the startup landscape.

Regarding funding on Exit type of rounds, it has been fluctuating over the years. The highest amount of funding through IPOs was in 2022 at €2 bn. The majority of companies (85%) having received Exit type of funding were founded before 2010. The results are consistent with the role of venture capital, which increases to flow in startups at higher development stages.

Figure 20: Annual funding in digital tech-based healthcare companies since 2010



Source: Technopolis Group based on Crunchbase, 2022

Digital technology related investments within healthcare

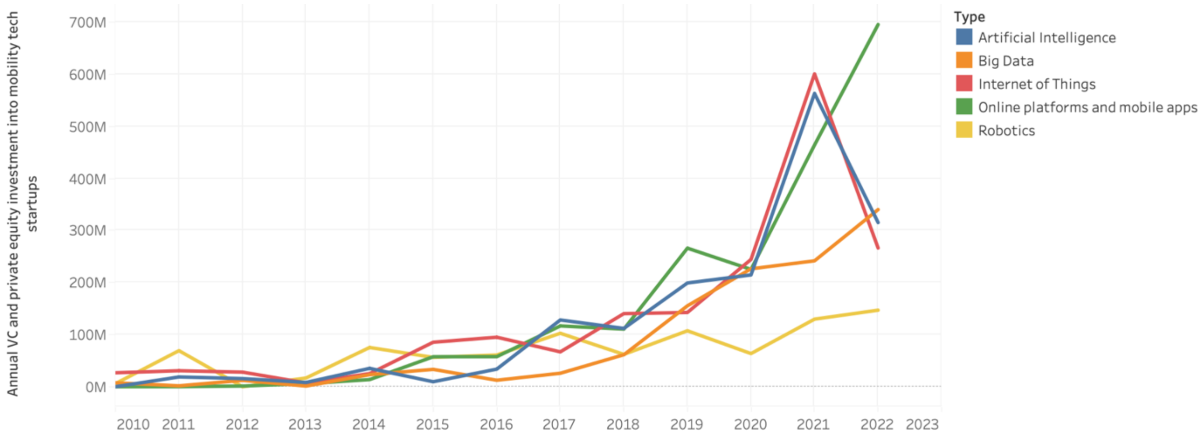
In healthcare, startups facilitating the digitalisation of the healthcare ecosystem by offering **online platforms** have had a **stable growth** in investments over the last decade and gathered a total of €2bn since 2010. Different online platforms are expected to transform the healthcare field beyond recognition, especially in a data-rich environment[80]. A very successful example is the French company **Doctolib**[81], which offers an online and mobile booking platform to help patients find doctors and make appointments. It has more than 60 million users and an estimated turnover of €200 m in 2020[82], being one of the greatest health tech success stories over the last years.

Artificial Intelligence (AI) is expected to reshape the current practice of healthcare, particularly in diagnosis and treatment recommendations, patient engagement and administrative activities. Due to great promises and expectations, AI-driven and IoT companies have therefore also seen a **sharp increase in the availability of funding** especially since 2016, with AI companies reaching a total of €563 m in 2021, which is more than four times their total funding in 2017. A good example is a German company **Ada Health**[83], an AI-enabled treatment provider founded in 2012, that has gathered a total of €189 m in 5 founding rounds.

Companies using **big data and analytics** at the core of their business model have also seen their market growing in the last years. However, the main type of funding is still seed and early VC, with only some companies leveraging bigger rounds of late VC after 2020. A clear outlier is the German company **ATAI Life Sciences**[84], focused in developing data driven approaches for mental health, it has secured access to almost €500 m in less than 5 years.

Robotics is also expected to have a far-reaching impact on many areas of the healthcare sector (i.e. surgeries, supply delivery, patient care), but the funding has remained somewhat lower compared to other above listed technology areas, reaching around €150 m in 2021.

Figure 21: Annual funding in healthcare related digital tech companies since 2010



Source: Technopolis Group based on Crunchbase, 2022

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[80] Eastwood, E. 2022. The 4 trends driving platform adoption in health care. https://mitsloan.mit.edu/ideas-made-to-matter/4-trends-driving-platform-adoption-health-care
[81] https://www.doctolib.fr/
[82] See also: https://www.france24.com/en/europe/20211224-success-of-online-medical-portal-doctolib-highlights-the-french-state-s-failure-to-digitise
[83] https://ada.com/
[84] https://atai.life/

4.2. Foreign direct investment into the health ecosystem

fDi intelligence[85] tracks cross-border greenfield investment both intra EU, extra EU and of course globally, covering the **health industrial ecosystem** among other industries. **It provides real-time monitoring of investment projects**, capital investment and job creation with powerful tools to track and profile companies that are active investors in the field. The data source tracks projects that are expected to create new jobs and do not cover merges and acquisitions (already part of the VC data analysis above).

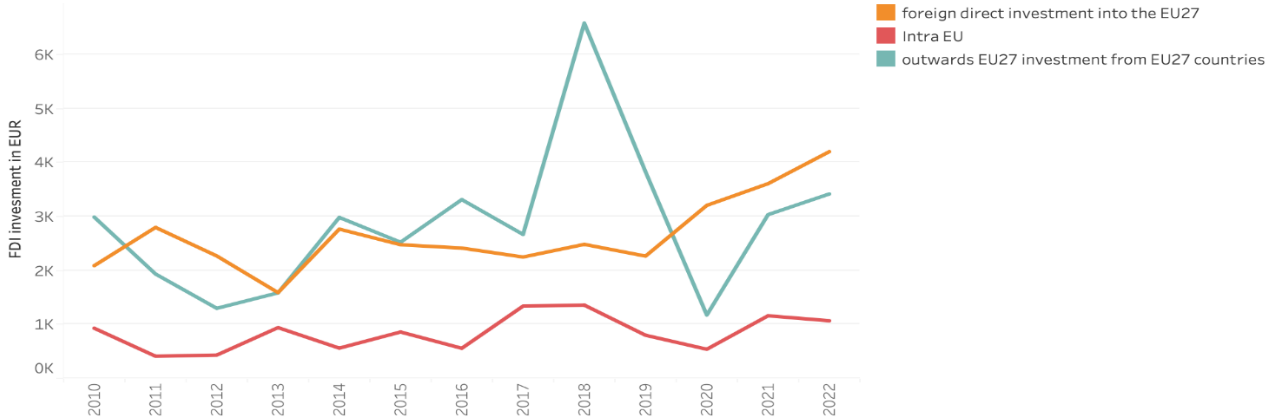
Figure 22 presents the total capital investment over time of foreign direct investment (FDI) health projects (from EU or to EU). The figure shows the evolution over time of total capital expenditure of health FDI projects from or to EU member states. Three categories of movement are visible: Intra EU (FDI projects from EU27 countries to EU27 countries), foreign direct investment from non-EU countries into the EU27, and outwards EU27 FDI from EU27 countries.

Until 2018, the European healthcare industry was actively investing abroad (see blue line) and solidified its global value chains and position as a global player (Figure 22). The increasing trend reached its peak in the period before the Covid-19 pandemic, particularly between 2017 and 2018, followed by a rapid drop, particularly in the first two years of the pandemic. In 2020, however, the negative trend arrived at a turning point when the industry started to invest more actively abroad again. As a result, the EU's outward foreign investment grew again for the first time since 2018, although it remained below the pre-pandemic level of investment. Obviously, both geopolitical turbulences since 2018 and the pandemic itself had a negative impact on the EU health ecosystem foreign investment and global interconnectedness. Over the past two years, the EU27 countries' outward foreign investments have been continuing to increase. Although the pre-pandemic level of investment has not yet been reached, the European healthcare ecosystem clearly remains an active investor abroad. This development illustrates that European health ecosystems' foreign investments are highly dependent on the global environment and fluctuate strongly depending on the situation.

In contrast to outward foreign investment, intra-European healthcare investments (see red line) are at an overall lower level having moved mostly in tandem with outward foreign investment since 2010. Intra-European investments and EU27 outward investments thus behave largely similar in their development. However, there are minor differences. In contrast to foreign investment, the downturn was not as sharp as in the case of intra-European investments and is closer of reaching the pre-pandemic level. Thus, illustrating that the domestic (European) healthcare ecosystem investments are more resistant to global shocks. The inflow of capital from outside the EU27 into the ecosystem (orange line) shows a similar trend like intra-European investments. However, since 2019, the inflow of foreign capital has grown significantly faster than the intra-European investment.

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

Figure 22: Foreign direct investment in the health ecosystem



Source: Technopolis Group calculations based on fdiInsights, including the following industries automotive components, automotive OEM and transportation

4.3. Public procurement supporting the digital and green transition of the health ecosystem

Public authorities are major consumers and can use their spending power to transform the market of many industries. By procuring environmentally friendly goods, solutions, and services public authorities can contribute to the green transition of economies. Through innovative public procurement governments can foster the uptake of innovative goods and services. Given the role public procurement can play in accelerating the transition and the expectation of its increased uptake by EU countries, it is an important building block of the analysis about investments and funding.

To monitor the twin transition in public procurement in the field of the entire ecosystem, we based our analyses on the Common Procurement Vocabulary (CVC) classification system and keywords. We focus thereby on green and digital products, goods or services that were procured by public institutions. The main source for this analysis has been the Tenders Electronic Daily, the online version of the 'Supplement to the Official Journal' of the EU, dedicated to European public procurement. The period in focus from 2015 until today allowed an analysis over time including up to date information.

The analysis indicates that the value of public procurement in the healthcare domain was the main object of procurement in EU27 countries, amounts to €48.9bn in the period 2015-2020.

Public procurement in the sphere of twin transition amounts to €0.5bn representing 1.04% of the total procurement value on healthcare, which is in turn 3 % of the total number of notices published.

The results show also that green transition accounts for 0.98% of total procurement value and 2 % of the total number of published notices. The value of notices procured by governments regarding the digital transition is close to 0.06% while the notices published in digital transition correspond to 1 % of the total number of notices published.

The most notable growth in numbers of notices in the field of green transition stems from energy and durability with an average annual growth of 39% and 22% respectively. In terms of absolute value, there was a considerable growth in durability with very high average annual growth rates of 103% in the period 2015-2022.

The analysis shows that health data has the highest increase in notices for digital transition with an average annual growth of 10%.

The main government function, under which the largest expenditures were made was the field of health with 83.75%. In contrast, the field of environment accounts for approximately 0.38 % of expenditures in the period 2015-2022.

Among all references, durability and recycling were the most common references made in notices covering health as an object of procurement in the green transition. Recycling is often found to be the main requirement of the notices of new medical equipment. A typical request requires help in recycling old medical equipment, or the new equipment must be made out of recycled material. Durability is commonly found in the context of electrical medical devices.

With regard to the digital transition in public procurement of healthcare, interoperability and telecare are found in notices covering the digital transition as an object of procurement. More specifically, interoperability is commonly found when hospitals are upgrading their software systems or in other cases trying to communicate with hospital systems between different countries. Furthermore, telecare, telehealth and eHealth within the notices are usually used interchangeably. When they are the object of the procurement, it is mainly related to work with seniors or social work within the community.

Figure 23: Public procurement in the field of healthcare

Source: Technopolis Group based on TED, 2022

4.4. EU research and innovation funding into the digital and green transformation of healthcare

In this project, Horizon 2020 data was analysed with regard to digital and green transition related investments within the healthcare 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 839 projects classified under healthcare (see Appendix B regarding the relevant codes used) with a total funding of €4.4 bn in 2014-2020.

The digital transition related projects accounted for €1.1 bn and the green transition related project for €527 m within the total funding.

Among the funded projects, ICT projects accounted for 35% of the total funding according to the coding available in CORDA, followed by Nanotechnologies, Advanced Materials, Biotechnology and Advanced Manufacturing and Processing (NMBP) (13%) see Table 1.

Zooming in on the technologies as defined in the technologies defined in the methodological report (link), Table 2 outlines the total cost per technology related to the healthcare industrial ecosystem. The highest digital technology related funding went into projects focusing on advanced manufacturing and robotics and artificial intelligence.

Table 1: CORDA EU R&I funding in healthcare

Technology - High level (coded in CORDA)	Total Cost	FP Contribution	Other investement	Share in total (using Total cost)
Climate action, environment, resource efficiency and raw materials	88.052.753	80.415.418	7.637.335	2%
Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy	287.252.203	271.940.528	15.311.675	7%
ICT	1.564.487.476	1.035.793.240	528.694.236	35%
NMBP	554.861.580	516.386.528	38.475.052	13%
Smart, green and integrated transport	171.792.445	141.463.496	30.328.950	4%
Total	**2.666.446.457**	**2.045.999.209**	**620.447.248**	60%
TOTAL Health	4.408.136.614	3.451.196.890	**1.233.257.161**	100%

5. Skills demand and supply

Key findings

The supply and demand of skilled professionals relevant for the green and digital transition has been captured by LinkedIn and Cedefop data. The skills needs in the health ecosystem is undergoing major changes. Improvements including upskilling, reskilling, interdisciplinary skills are necessary as advanced digital and especially green competences and skills in the health ecosystem are still low and lack of skills is considered as a main barriers to the digital transition in healthcare.

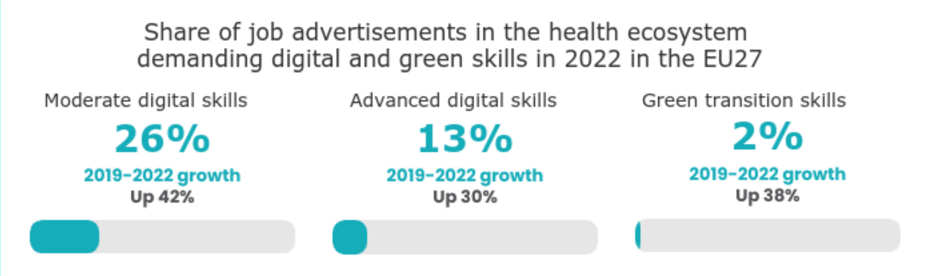
Within the registered professionals on LinkedIn employed in the healthcare industrial ecosystem, **6.3% possess advanced digital skills** (including technological knowledge such as AI, IoT, big data, electronic health records etc.), while only **2.9% have environmental protection related skills** (green skills).

Professionals with **digital skills** are most often required in the sphere of **healthcare services and hospitals** over pharmaceutical and medical devices development and production (which is most probably due to the electronic health record). The highest share of digital professionals is observed in the area of **big data, followed by IoT, cloud computing and AI**. Green professionals are mostly employed in the sphere of **energy management** and **recycling**.

The **fastest growing skills** in the health ecosystem are **data analysis**, **analytical skills and customers directed skills**. However, a variety of organisational and managerial skills are also often demanded.

On the demand side for skilled professionals, the analysis of online job advertisements shows that there were 2 058 390 job ads published in the healthcare industries in the year 2022. Within this total, the **job ads that can be related to digital technologies represented 26% in 2022 in the EU27 and to the green transition a much lower share of 2%.** Trends over time suggest a growing demand for digital skills but a much more limited interest in green transition related skills.

Figure 24: Share online job advertisements in healthcare demanding digital and green transition related skills



Source: Technopolis Group calculations based on Cedefop data, 2022

In summary, currently digital skills are heavily dominating the ecosystem over green skills, both in terms of already people employed in the ecosystem and profiles sought. The health ecosystem **must continue to invest in digital skills, but even more making efforts towards raising the awareness of the importance of green skills** in order to remain competitive in the changing landscape of global healthcare and successfully support the green transition of the ecosystem.

This section aims at analysing trends in the supply and demand of skilled professionals relevant for the green and digital transition based on data from different sources combining systematically collected data by official statistics, like Eurostat and experimental data from LinkedIn and Cedefop. Since there is a general lack of data about specific digital and 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, especially in the field of digital and green transition. In order to analyse the number of professionals working in the ecosystem, we focused on occupations with a high relevance for healthcare industry[86]. 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 28 European countries and was developed based on the collection and analysis of more than 100 million online job ads from July 2018 onwards.

Emerging societal challenges and technological trends ranging from reducing global warming to e-health records and AI-enabled medical devices, to name a few, require rapid changes in how healthcare is delivered to the society, for which both, green and digital skills are essential. At the same time, there is a general lack of digital skills among healthcare professionals, who present the biggest group of actors in the ecosystem.[87] Furthermore, lack of skills has been identified as one of the key barriers to the digital transition in healthcare[88] and most current national medical guidelines do not include digital skills and there is a lack of dedicated training opportunities for medical professionals, which further hampers the situation. Against this backdrop the need to upskill, reskill and implement interdisciplinary skills the European workforce in the healthcare ecosystemis becoming increasingly important to cope with evolving societal expectations and needs[89]. The problem has already been acknowledged by the EU policy makers. The European Skills Agenda[90] wasadopted by the EC in 2020, which aims to enable businesses to develop better green and digital skills 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[91]. Also, the World Health Organisation has launched a Global Strategy on Digital Health , which among other goals aims to promote and advocate the digital skills of the persons employed in the healthcare services[92].

5.1. Supply side: professionals with green and digital skills

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

[86] 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.

[87] Healthy Europe (2022). All Policies for Healthy Europe, https://healthy€ope.eu/wp-content/uploads/HE_DigitalSkills_final.pdf

[88] United Nations (2021). Boosting digital skills in healthcare. https://www.itu.int/hub/2021/05/boosting-digital-skills-in-healthcare/

[89] European Health Parliament (2016). Digital Skills for Health Professionals, https://www.healthparliament.eu/wp-content/uploads/2017/09/Digital-skills-for-health-professionals.pdf

[90] European Skills Agenda, 2021, https://ec.europa.eu/social/main.jsp?catId=1223

[91] Idem.

[92] World Health Organization, (2020). Global Strategy on Digital Health, https://cdn.who.int/media/docs/default-source/documents/gs4dhdaa2a9f352b0445bafbc79ca799dce4d_02adc66d-800b-4eb5-82d4-f0bc778a5a2c.pdf?sfvrsn=f112ede5_68

More than 9 out of 10 jobs in the EU require digital skills, putting them among the top 10 most demanded skill[93,94] Unfortunately, in the survey conducted by the European Health Parliament, showed that of the majority of health professionals have received no training or insufficient training in advanced digital technologies[95]. Another recent survey found that an average score in technological skills of healthcare workers is only 4.7 out of 10, which is an unsatisfactory level for potential employers[96]. Furthermore, according to the WHO, in 2022, the knowledge on how to best equip the health industry with necessary digital skills is still lacking[97].

In general, the market supply of labour is the number of workers/professionals of a particular type and skill level who are willing to supply their labour to companies. LinkedIn data can measure this supply by providing insights about the number of professionals on the market with green and digital technological skills relevant to the health industrial ecosystem. To harvest the data from LinkedIn, keywords 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.

(Advanced) Digital skills have been defined in the context of the main digital technologies captured in this project notably in artificial intelligence, cloud computing, connectivity, robotics, Internet of Things, augment and virtual reality and block chain, but in the case of healthcare also including electronic health records, medical data handling, medical robotics etc.

Keywords were subsequently used to construct queries for searching the database. As the healthcare ecosystem is broad, to deliver more meaningful insights we investigated the skills profiles of health professionals in **three specific sub-industries**, notably: **1) healthcare services and hospitals 2) pharmaceuticals and 3) medical devices.** The analysis of the LinkedIn data provides some interesting insights about the availability of green and digital professionals in the ecosystem in EU27 countries. Figure 25 shows the findings about the share of profiles of healthcare professionals that indicated a green transition or digital transition related skill.

Within the registered professionals on LinkedIn employed in the healthcare industry, professionals with **digital skills** are most often mentioned in the sphere of **healthcare services and hospitals,** driven by skills on electronic health records. Interestingly, the data indicates that, only around **6%** of the total jobs in the industrial ecosystem involves advanced **digital skills** (even if it has to be kept in mind that not everyone would indicate the digital skill in particular on their profiles, hence this percentage has to be interpreted also as a perception). If we exclude more 'basic' digital skills related to health records, we find that professionals in medical devices mentioned most often digital skills such as big data or artificial intelligence.

The highest share of digital professionals is observed in the area of **big data,** with 3.2% in medical devices sub-section. Furthermore, digital professionals are also particularly often employed in the field of **IoT, cloud computing and AI**. The highest level of

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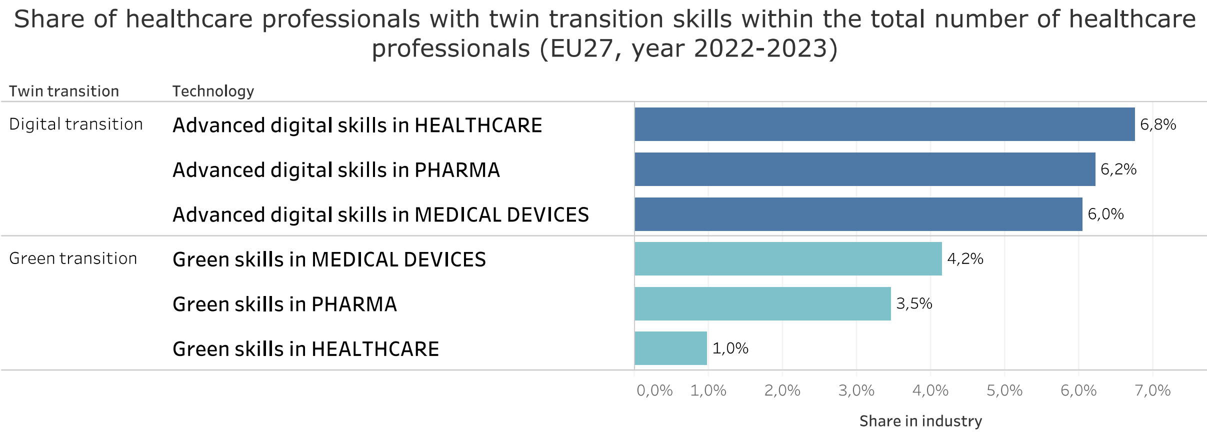
[93] European Commission, 2017, The digital skills gap in Europe, https://digital-strategy. ec.europa.eu/en/library/digital-skills-gap-Europe
[94] President of the EU Commission, Ursula von der Leyen's 2022 state of the union address came with the announcement that 2023 will be the European Year of Skills. 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.
[95] European Health Parliament, 2016 Digital Skills for Health Professionals, https://www.healthparliament.eu/wp-content/uploads/2017/09/Digital-skills-for-health-professionals.pdf
[96] University Oberta de Catalunya, Healthcare professionals lack the digital skills required by the market. https://www.uoc.edu/portal/en/ehealth-center/actualitat/noticies/noticia_035.html
[97] WHO, 2022 Towards a digitally capable health workforce in Europe, https://www.who.int/europe/news-room/events/item/2022/11/17/default-calendar/towards-a-digitally-capable-health-workforce-in-europe--approaches-to-developing-digital-skills-and-competencies

advanced digital skills among different profession groups belongs to managers (product and project managers) and software developers. Healthcare practitioners (i.e. nurses, medical doctors, residents, researchers) can all be described with rather equal level of advanced digital skills, with some insignificant minor variations.

On the other hand, the LinkedIn data indicates that a **significantly lower level** of healthcare professionals have **skills relevant for the green transition**. Therefore, there is a more varied picture for green skills, where it is only **1% of healthcare and hospital professionals** that indicate skills relevant for the green transition compared to **medical devices where this share is 4.2% and pharmaceuticals where it is 3.5%**. Hence, it can be concluded that companies tend to have up to six times more professionals with digital skills than professionals with green skills in the healthcare ecosystem. Green professionals are mostly employed in the sphere of energy management (i.e. especially in hospitals and 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. In terms of professionals, according to the LinkedIn data, project and product managers have most frequently advanced digital skills, followed by software engineers and high-level executives. Healthcare professionals (i.e. nurses, doctors and researchers) have all significantly lower skills level (or at least mention these skills less often).

Figure 25: Share of professionals in total employed in the healthcare industrial ecosystem with green and advanced digital skills and with a profile on LinkedIn



Share of healthcare professionals with a specific technological skills within the total number of healthcare professionals (EU27, year 2022-2023)

Technology	Sub-industry: Medical devices	Pharmaceuticals	Healthcare
Big Data	3,2%	1,7%	0,8%
IoT	2,3%	0,2%	0,2%
Cloud	1,5%	0,7%	0,3%
Artificial Intelligence	1,4%	0,6%	0,4%
Energy management	0,9%	0,4%	0,1%
Robotics	0,8%	0,2%	0,1%
Cybersecurity	0,5%	0,2%	0,1%
Recycling	0,2%	0,2%	0,1%
Augmented and virtual reality	0,1%	0,1%	0,1%
Blockchain	0,1%	0,1%	0,0%

Source: Technopolis Group based on LinkedIn data, 2023

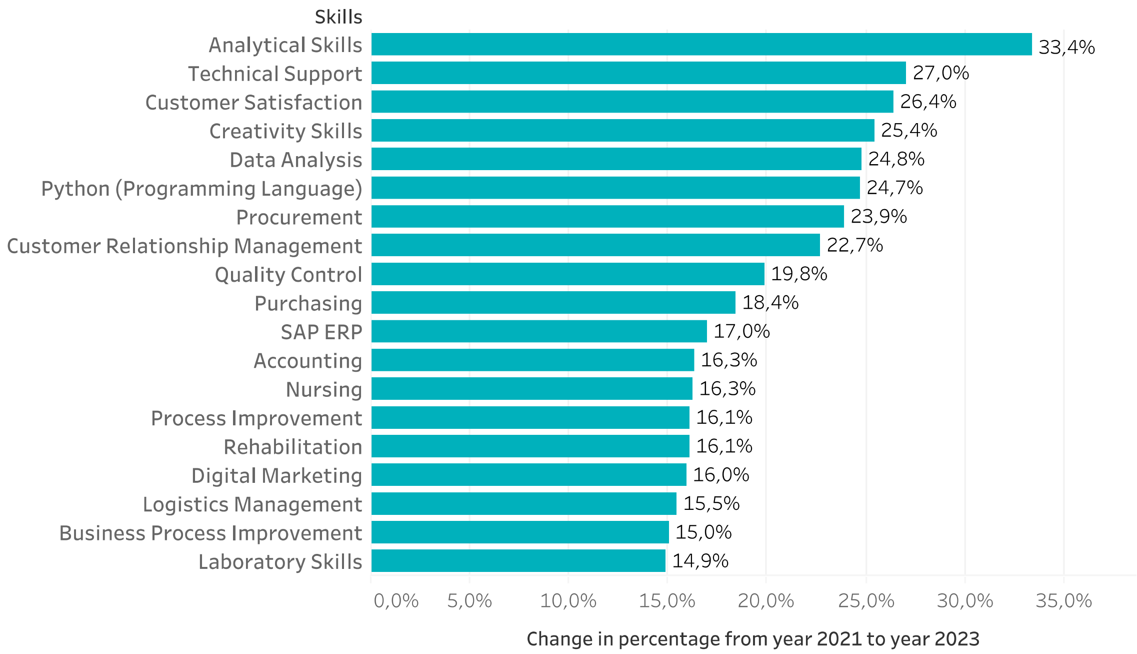
Progress over time

The change in the number of professionals with advanced digital or green skills have to be put in the context of the overall employment patterns. The total number of professionals on LinkedIn employed in the healthcare industrial ecosystem (healthcare, pharmaceuticals and medical devices) has increased during 2019-2020 and also from 2020 to 2021 (annual

+3%) and stayed close to stable from 2022-2023 (+0.4% increase). The share of professionals with digital skills has witnessed a steady growth over the past years: the number of advanced digitally skilled professionals grew by 14% and green skills 6% within the EU healthcare ecosystem (including all three sub-industries) over the period from 2021-2023 on LinkedIn.

Based on the defined industry-related skills, which were evaluated and confirmed by industry experts, the highest growing technological skills among professionals in the healthcare ecosystem are presented in the Figure 26 below. When it comes to the fastest growing groups of skilled employees in the healthcare ecosystem, **there is a strong growth of analytical skills, technical support and customer satisfaction that are on the top of the chart**. The analysis shows that due to rapid advancements of different digital technologies in the healthcare ecosystem, analytical skills in general and (data) analytics in particular together with various programming languages and specific IT skills, such as Python and SAP have grown strongly. In addition, need of skills directed towards customers, have increased significantly, such as technical support, customer satisfaction and customer relationships management, due to rapid increase and availability on one side of different online e-services for the patients and on other side general uptake of different digital solutions in the healthcare ecosystem. The data indicates that analytical and programming skills are more pronounced among digital professionals. In addition, there is a wide range of organisational, coordination, and managerial skills, such as quality control, process improvement, logistics management, business process improvement. A number of administrative skills have also increased significantly, such as procurement, purchasing, accounting, together with specific personal skills, such as creativity, which are all in a very high demand.

Figure 26: Fastest growing technological skills among professionals employed in the healthcare industrial ecosystem



Source: Technopolis Group calculations, 2020 and 2022

5.2. Demand for green and digitally skilled employees

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

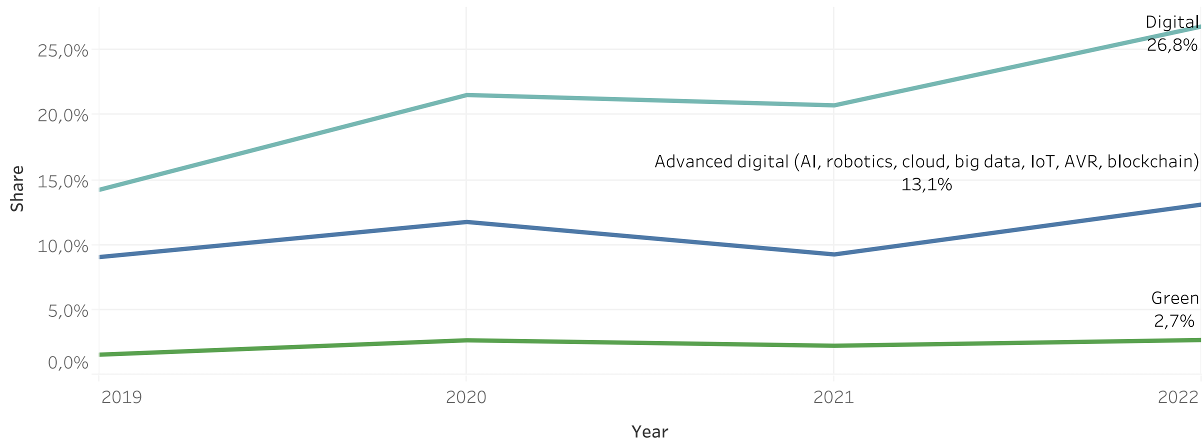
Specific to the healthcare industrial ecosystem[98], **there were 6 267 741 unique job advertisements from companies between 2019-2022 in the EU.** The number of online job advertisements within healthcare in EU27 countries amounts to 2 058 390 in the year 2022. Skills have been analysed related to the green and digital transitions. The green pre-defined skills are from ESCO v1.1 and the digital are predefined from ESCO v1.1.1 which is currently being updated.

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

  Within digital skills, we distinguished between general digital skills (that do not include basic Microsoft office skills but include specialised software used in the industry, the use of statistical software etc) and advanced digital skills (a category that is filtered for digital technologies including AI, big data, robotics, IoT, cloud, augmented and virtual reality, blockchain). Please note that the general digital technology category includes also the skills related to advanced digital technologies.

Online job advertisements that can be related to general digital technologies amount to 1 350 471 over the period from 2019-2022, and to green transition related skills amount to 146 763. **The share of digital and green transition related job ads has been increasing over time and reached 26% for digital and 2.7% for green in 2022 that demonstrates a growing demand for digital and green skills.**

Figure 27: Share of online job advertisements that demand digital and green transition related skills within the total number of job advertisements in the healthcare industrial ecosystem

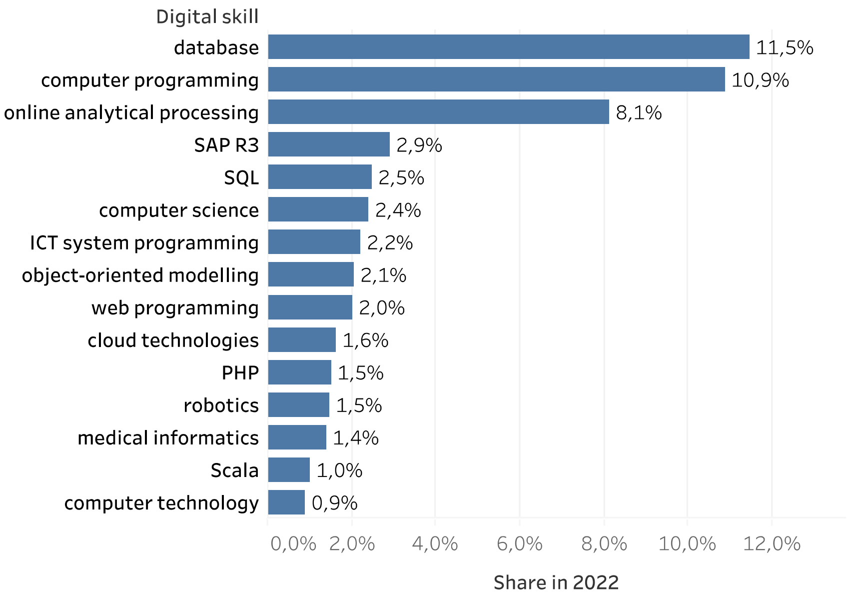


[98] In the case of the healthcare industrial ecosystem the dataset was filtered for the NACE industries as defined in the Annual Single Market Report

Source: Technopolis Group calculations based on Cedefop data, 2023

The top 15 digital skills including advanced and general skills (but without basic Microsoft office skills) that appeared most often on healthcare related online job advertisements over the period from 2019-2022 are presented in the Figure below. As it is expected digital skills that are the most relevant include knowledge about handling databases that are relevant in particular for electronic health records.

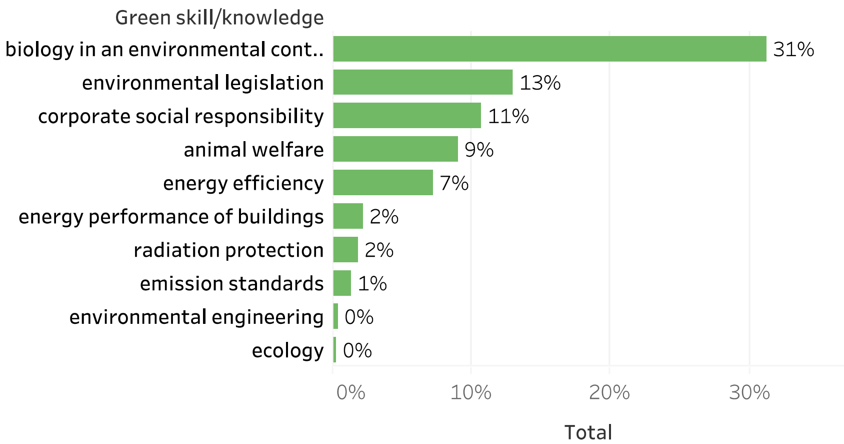
Figure 28: Top digital skills on job advertisements in healthcare (2019-2022) in the EU27



Source: Technopolis Group calculations based on Cedefop SkillsOvate data, 2023

Green transition related skills are significantly more limited compared to digital. The more sought-after green skills are presented in the Figure below.

Figure 29: Top green skills on job advertisements in healthcare (2019-2022) in the EU27



Source: Technopolis Group calculations based on Cedefop SkillsOvate data, 2023

6. Sustainable competitiveness: the green performance of the ecosystem

Key findings

Worldwide, the healthcare industry is responsible for approximately **7.2% of total GHG emission, contributing to a large extent to global warming.** Majority of the emissions are caused by the healthcare supply chain, through the production, transport and disposal of goods and services. **The healthcare industry is also above average global resource consumer in terms of raw materials, where an upward trend regarding material consumption can be observed**. Even though healthcare contributes increasingly to damage to the natural ecosystem, it **remains way below the global average in cross-industry comparison of this study in terms of ecotoxic emmission, water and land use.**

Waste is a major issue for this ecosystem. The **majority of waste produced (around 85%) is non-hazardous** (i.e. paper, cardboard, and plastics, discarded food, metal, glass, textiles, and wood) and can be recycled and only 15% of waste from the health ecosystem is potentially infectious, toxic, radioactive, and/or capable of other environmental and health risks and shall be subject to a special treatment. **Waste reduction and management is therefore becoming increasingly important for circularity and green performance of the healthcare ecosystem.**

6.1. Environmental challenges of the healthcare ecosystem

The health ecosystem was responsible for 5% of greenhouse gas emission of all industrial ecosystems in the EU27 in 2022. There are growing concerns over environmental challenges (i.e. climate change and the need to reduce GHG emissions) and consensus that further steps towards more sustainable health systems is a must. Its negative implication on natural environment is primarily linked to the emissions caused by the healthcare supply chain, through the production, transport and disposal of goods and services, amounting total to around 71%, followed by emissions from health care facilities and health care owned vehicles (17%) and indirect emissions from electricity, steam, cooling and heating (12%)[99]. But not only the emission is a serious ecological issue. Healthcare produces an increasing waste stream (e.g. plastics, single-use items and drugs), creating negative environmental effects and pollution that cause damages of human health and endanger biodiversity. Basically, any activity, connected directly or indirectly to healthcare services can potentially contribute to environmental harm.

With the aim to measure the trends in the environmental impacts, this section draws upon data from Eurostat and Exiobase. The green transition impacts are sourced from Eurostat and Exiobase 3.8[100]. Whilst Eurostat represent the official statistics, Exiobase is a legitimate source of information referred to for example by the European Environmental Agency[101],

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[99] Health Care without Harm, 2019, Health Care Climate Footprint Report, https://noharm-uscanada.org/ClimateFootprintReport

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

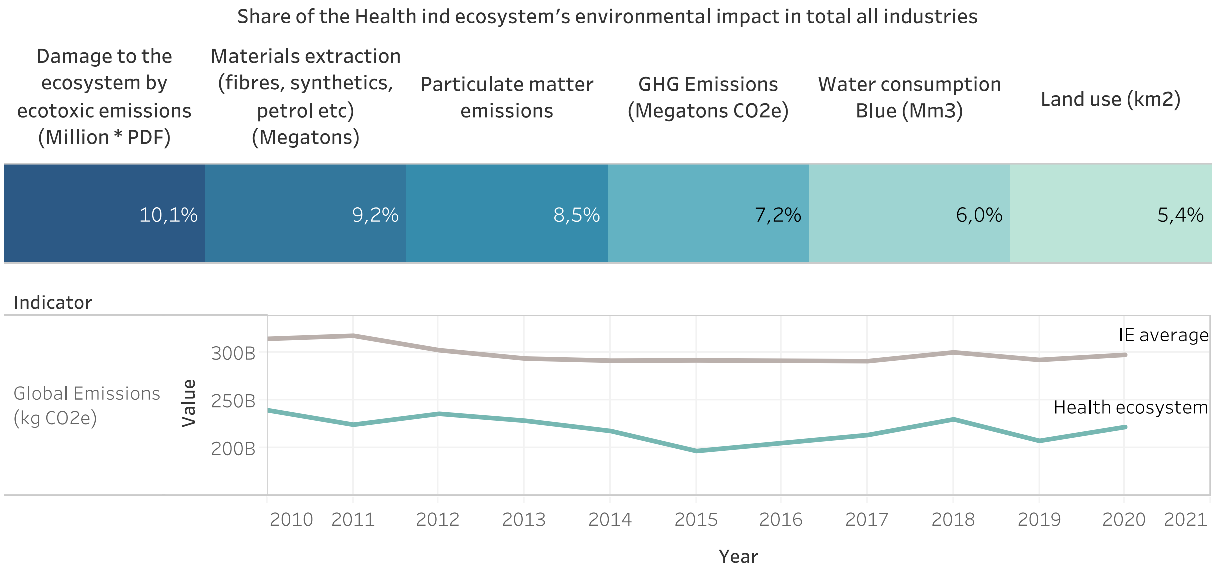
[101] EEA, 2022. https://www.eea.europa.eu/data-and-maps/data/external/exiobase

the EC/JRC community[102], Eurostat[103], and by the European Commission to propose the regulation on carbon border adjustment mechanisms[104]. Pressure to environments refer to trade-embodied resources utilisation, and trade-embodied impacts. Resources utilisation is captured with four main dimensions are considered for cross-industry comparisons: embodied Land use, embodied Water consumption, embodied Materials Consumption, and Energy mix supplied to the industrial activity. In terms of impacts, there are three dimensions monitored: Air emissions (incl. GHG), Waste generation, and damage to the ecosystem.

The European healthcare ecosystem is undergoing a green transition and transforms towards higher sustainability and environmental friendliness. This transition involves moving away from fossil fuels and other unsustainable practices and towards cleaner sources of energy, more efficient use of resources, and more sustainable production and consumption patterns. Hence, **monitoring and understanding the use of resources is a key measure for sustainable healthcare ecosystem**. In this section, we aim define and measure the trends in the above-mentioned environmental impacts.

The Table 13 below shows the summary of green performance indicators at EU level and its change from 2010 to 2021. Overall, the analysis suggest that the **most relevant environmental challenges of the health ecosystem are related to damage to the environmental ecosystem and materials extraction**.

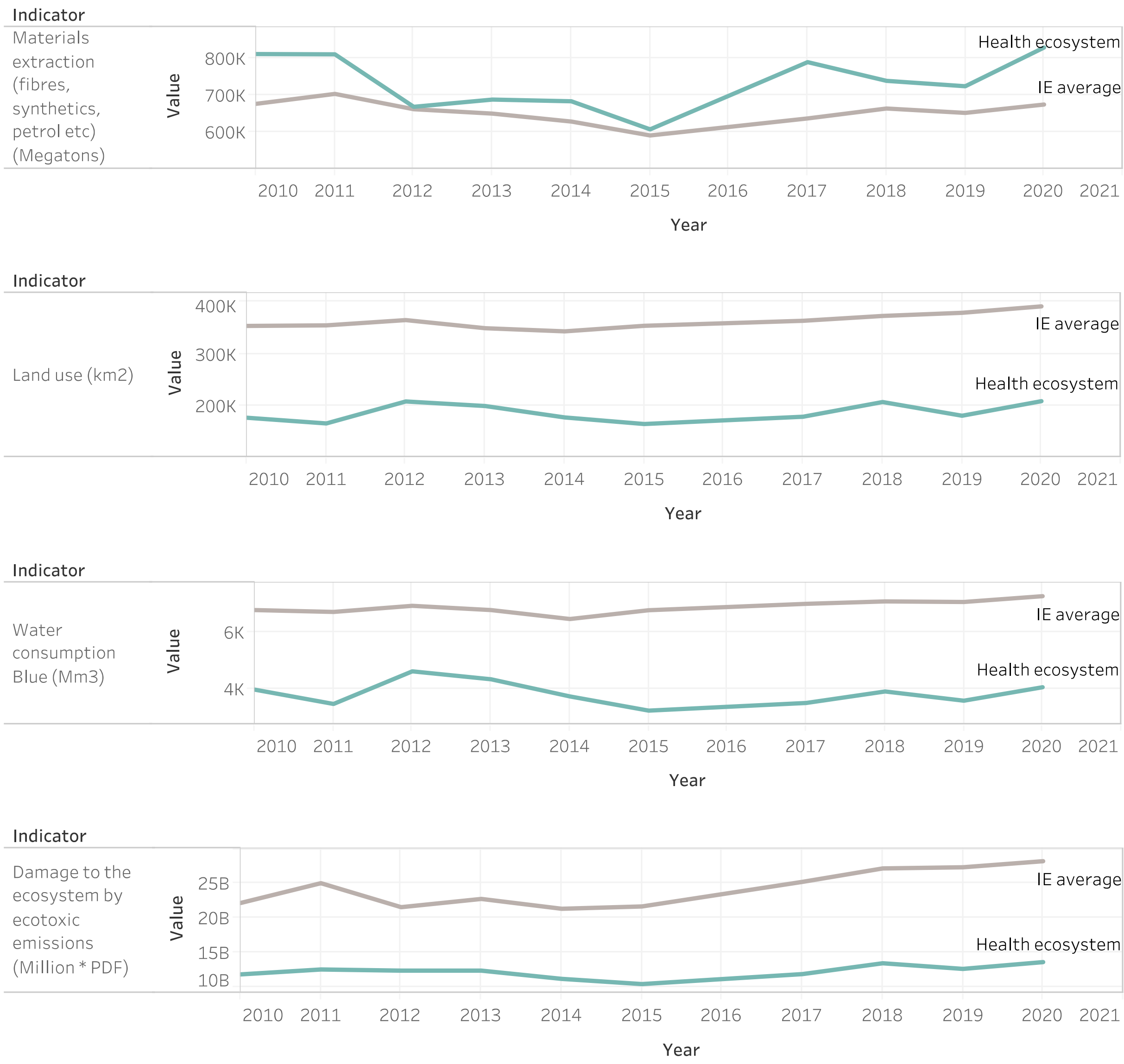
Table 30: Environmental indicators that capture the environmental impact of the health industrial ecosystem, including both production and consumption accounts based on Exiobase data



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

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

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



Source: Technopolis Group, 2022, based on Exiobase data

Emissions

Emissions in the health ecosystem refer to the release of pollutants into the atmosphere as a result of different production and services (including transportation) activities. As the world becomes more aware of the potential negative impact of healthcare industry on the environment, there is a growing emphasis on reducing emissions in the healthcare ecosystem. This is being achieved through a variety of means, including the construction of more environmentally friendly healthcare facilities or the promotion of sustainable transportation options for healthcare service providers, to name a few. Furthermore, due to novel digital solutions, it is possible to reduce the healthcare-related transportation services in general, by adopting teleconsultations and e-health services. In terms of GHG emission of CO2, the health industrial ecosystem's outputs are below the industrial average for the most part originating from accommodation and food servies and air transport. **Healthcare contributes to 5% of the total GHG emissions of all industrial ecosystems.** Comparing the emissions of the last ten years, overall emission levels stayed stable and dropped in total 17 Megatons between 2010 and 2020. The majority of emissions in the healthcare ecosystem originate from accommondation and food services, but also (air) transport and medical, surgical and orthopaedic appliances manufacturing. These emissions contribute to climate change and air pollution, which in turn contribute to environment-related threats to human health[105].

Resource consumption

Indicators for the resource consumption feature materials extraction (fibres, synthetics, petrol, etc.), land use (km^2) and water consumption (Mm^3), respectively. The **healthcare** industry **is a significant contributor to global resource consumption in terms of raw materials**. Regarding raw materials, the industries' demand is particularly high for different metals and plastic. Different health services related activities reduced slightly its contribution in the ecosystem from 51% to 43% in the period. Second driver is manufacturing of medical and surgical equipment and orthopaedic appliances, reducing slightly its contribution to the ecosystem from 34% to 20% in the same period. In terms of **water consumption and land use**, the healthcare industrial ecosystem is significantly below the global average and contributes 4% and 3.8% accordingly. There is mainly one large contributor to both, land use and water consumption - health services related activities, with a contribution of 50% for land use and 46% for water.

Biodiversity loss

In this study, biodiversity loss could be only captured by data on ecotoxic emissions. This indicator shows that the **health industrial ecosystem increasingly contributed to damage to the natural ecosystem since 2015 but remained significantly below the global average.** Main driver is the manufacturing of medical and surgical equipment and orthopaedic appliances that increased its contribution in the health ecosystem from 67% in 2010 to 73% in 2021. Second driver is health services related activities, which reduced its contribution in the healthcare industrial ecosystem from 23% to 16% in the same period of time.

6.2. Circular economy

The European healthcare ecosystem plays a major role in the economy as a key producer or purchaser of different goods and services, including consuming large amounts of energy and water, building materials, pharmaceuticals, medical devices, which cause not only massive environmental pollution, but also waste generation[106]. For example, hospitals produce approximately 13kg waste per bed in a day[107]. The majority of waste produced (around 85%) is non-hazardous (paper, cardboard, and plastics, discarded food, metal, glass, textiles, and wood) and can be recycled[108] and only 15% of waste from the health ecosystem is potentially infectious, toxic, radioactive, and/or capable of other environmental and health risks and shall be subject to a special treatment[109]. Despite by the support from policy makers the transition to a circular economy in healthcare is still at an early stage and major improvements are needed to achieve the primary goal of waste avoidance and minimisation. Different options[110], such as multiple use and reuse of medical equipment, a low-waste material purchasing policy, prolonged use of medical hardware and an efficient storage can all offer solutions towards adopting circular economy principles in the healthcare ecosystem. This in turn requires new business models of companies, moving from one-way transactions of providing equipment through different service

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contracts, which includes for example refurbishing not only large medical devices and equipment (i.e. MRI machines), but also smaller, i.e. monitors and ventilators. Transition towards digitalisation will also play a major role in the circularity of the ecosystem, by enabling telemedicine together with extended performance of equipment via predictive maintenance, it reduces material and energy, resulting in reduced Co2 emissions[111].

Waste reduction has a high importance 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, sterilization trays etc.). Furthermore, during the COVID-19 pandemic, the waste issue (i.e. increased use of gloves and sterilisation material) became especially acute. Furthermore, the estimated proportion of masks in litter increased from less than 0.01% to 0.8% as a result of the legislation.[112]

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Appendix B: Methodological notes

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: Alternative Medicine, Assisted Living, Assistive Technology, Biopharma, Clinical Trials, Cosmetic Surgery, Dental, Diabetes, Electronic Health Record (EHR), Emergency Medicine, Fertility, First Aid, Genetics, Health Care, Health Diagnostics, Home Health Care, Hospital, Medical, Medical Device, mHealth, Nursing and Residential Care, Outpatient Care, Personal Health, Pharmaceutical, Psychology, Rehabilitation, Therapeutics. 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	300
C33	Manufacture of medical and surgical equipment and orthopaedic appliances	100
Q86	Human health activities	69

Foreign direct investment data analysis

The selected tags are presented in the Table below:

Sector	Sub-sector
Healthcare	Outpatient care centres & medical & diagnostic laboratories
	Offices of physicians, dentists, & other healthcare practitioners
	Other (Healthcare)
	General medical & surgical hospitals
	Nursing & residential care facilities
	Psychiatric & speciality hospitals
	Home healthcare & all other ambulatory health care services
	Social assistance
Medical devices	Medical equipment & supplies
	Electromedical and Electrotherapeutic Apparatus
	Other (Medical devices)
Pharmaceuticals	Pharmaceutical preparations
	Medicinal & botanical
	Health & personal care stores
	Other (Pharmaceuticals)

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

TED data analysis

LinkedIn data analysis

Categories selected: Hospital and Healthcare, 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