1 OVERALL ENVIRONMENTAL FOOTPRINT OF THE HEALTH SYSTEM

1.2 Material environmental footprint of the healthcare sector (ENV-2)

1.2.1 Documentation sheet

Description	**Primary indicator**: A. Annual material environmental footprint of the healthcare sector, in kg per capita **Secondary indicator(s):** B. Annual material environmental footprint of the healthcare sector, in kilo tonnes C. Annual material environmental footprint of the healthcare sector, as a share of total material environmental footprint
Rationale	Demand for healthcare is expected to continue increasing due to population ageing, expanding medical treatment options and rising expectations regarding access and quality of care. [1-3] This growth leads to higher demand for healthcare infrastructure, medical devices, pharmaceuticals and consumables, all of which rely at least partly on primary material extraction. At the same time, healthcare delivery has become increasingly material-intensive, with a marked shift towards single-use products over the past decade, driven by infection prevention requirements, regulatory standards, cost considerations and ease of use. [1, 4, 5] Material extraction and processing are major drivers of resource depletion, land-use pressures, biodiversity loss and water stress, making material use a key dimension of environmental sustainability. [6, 7] The material environmental footprint captures all raw materials extracted – domestically and abroad – and used directly and indirectly to satisfy healthcare demand. This perspective is particularly relevant for healthcare, as a large share of its environmental impacts occur upstream in international supply chains. [7-10] Resource extraction includes biomass (e.g. cotton, wood, starch crops), fossil energy carriers (e.g. crude oil, natural gas, coal), metal ores (e.g. iron ore, copper ore, aluminium ore, lithium) and non-metallic minerals (e.g. sand, limestone, gypsum, mineral salts). Healthcare systems account for substantial shares of material extraction, notably biomass for medical textiles, paper and food provision; fossil resources for plastics and synthetic polymers, energy-intensive production processes, heating and transport; metal ores for infrastructure, machinery, batteries and medical equipment; and non-metallic minerals for construction and renovation, medical devices and pharmaceutical ingredients. [7, 10] Traditionally, medical devices and consumables follow a linear “make-use-dispose” model, with logistics and organisational practices focused primarily on waste management rather than reuse. [1, 11] From an environmental sustainability perspective, this contributes to rising material footprints and increasing dependence on primary resources. Circular economy strategies offer opportunities to reduce material footprints by maintaining material value for longer, reducing new extraction and improving supply resilience. In healthcare, this involves rethinking product design, procurement and use in line with the hierarchy of R-strategies (Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover), while safeguarding patient safety, quality of care, performance and cost-effectiveness. [11, 12] Because circular solutions may involve trade-offs, such as increased energy or water use for sterilisation, enhancing circularity and reducing the material footprint should be pursued using life-cycle assessments (LCA) of medical products to avoid shifting of environmental burdens to other impact categories. [1, 4, 5, 10]
Calculation	Material footprint was calculated by VITO (see methodological note) **Primary indicator (A):**

	• Numerator: Annual material footprint of the healthcare sector, in kg • Denominator: Population of the corresponding year (calculated as mean of population at beginning and end of year) **Indicator B:** • Numerator: Annual material footprint of the healthcare sector, in kilotonne • Denominator: / **Indicator C:** • Numerator: Annual material footprint of the healthcare sector, in kg • Denominator: Annual material footprint over all sectors, in kg
Data source	Environmental footprints were calculated by VITO using an Environmentally Extended Multi-Regional Input-Output (EE-MRIO) approach (see methodological note). Longitudinal results are reported for the period 2010-2023, while the cross-sectional structural decomposition is presented for 2022. Environmental impact data for 2023 were not yet available; therefore, preliminary estimates for that year were derived by combining 2022 environmental intensities with 2023 monetary data. As no adjustment for inflation was applied, these preliminary 2023 estimates are likely to overstate environmental impacts. Consequently, 2022 is considered the last year with fully reliable data and is used as the reference year in the interpretation and discussion of results. Population data from Eurostat. [13]
Technical definitions	See methodological note for the material footprint calculated by VITO. Material use is measured in kilograms of materials extracted and used, classified into four material categories: biomass, non-metallic minerals, metallic ores, and fossil energy carriers. For the international comparison, results from Andrieu et al. (2023) for the latest available year (2015) are used. [7] The study applies a top-down environmentally extended multi-regional input-output (EE-MRIO) approach to estimate the material footprints of the healthcare sector in 44 countries, including all EU Member States, as well as five aggregated regions representing the rest of the world. The analysis relies on EXIOBASE v3.8.2 to trace global supply chains and quantify the material footprint of the healthcare sector. Healthcare expenditure data are sourced from the WHO and OECD Health Expenditure Database. Capital formation is accounted for. Results derived from EXIOBASE are not directly comparable to those obtained using FIGARO, which is applied for the main analysis. For example, while FIGARO includes a dedicated pharmaceutical sector, EXIOBASE groups pharmaceuticals within a broader “chemicals not elsewhere classified” category, which may result in less precise estimates for healthcare-relevant supply chains (see methodological note).
International comparability	Given substantial differences in methodologies, data sources and underlying assumptions, international comparisons should be interpreted with caution and preferably limited to results derived from the same modelling framework. Andrieu et al. (2023) provide internationally comparable estimates of the material footprint of the healthcare sector for the year 2015 (see above in technical definitions). [7] The methodology applied in this study differs from the approach used for the primary and secondary indicators presented here, and results are therefore not directly comparable.
Limitations	See methodological note
Dimension	Environmental sustainability
Related indicators	ENV-1 GHG environmental footprint of the healthcare sector ENV-3 Land use environmental footprint of the healthcare sector ENV-14 Total annual primary waste in the healthcare sector
Supervisor	Nicolas Bouckaert
Reviewer	Pieter Fonteyn (VITO)

1.2.2 Results

BELGIUM

Table 1, Figure 1 and Figure 2 present the annual material footprint of the health system over the period 2012-2023, expressed both per capita (Figure 1) and in absolute terms (Figure 2), and disaggregated by material type. The total material footprint ranged from 1 084 kg per capita (11 998 kilotonne) in 2012 to 1 042 kg per capita (12 131 kilotonne) in 2022. Thus, the total footprint in 2012 and 2022 is of a similar absolute magnitude despite growth in healthcare output over the period, which is reflected in a slightly lower per capita value in 2022. However, substantial variability is observed over time. Following an initial decrease between 2012 and 2016, reaching a low of 848 kg per capita (9 573 kilotonne), the footprint increased again due to higher current spending and investment levels. This was followed by a COVID-related peak reaching a maximum of 1 151 kg per capita (13 293 kilotonne) in 2021, and a subsequent decline.

In terms of material composition, non-metallic minerals clearly dominate the footprint, consistently accounting for more than half of total material use (a 53% share in 2022; see Figure 6). This reflects the material intensity of healthcare-related construction, renovation and infrastructure, as well as the use of mineral-based inputs in medical products and pharmaceuticals. Biomass and fossil materials constitute the second and third largest components (each representing 19% in 2022; see Figure 6), while metals account for a smaller but relatively stable share (9% in 2022; see Figure 6).

Figure 1 and Figure 2 further show that current spending, which represents the main component of healthcare spending, accounts for the majority of the material footprint in all years, particularly for biomass and fossil materials. This reflects the ongoing consumption of medical goods, pharmaceuticals, energy and consumables. Investments, while smaller in absolute terms, account for approximately one fifth to one sixth of the total material footprint, which is higher than their share in total healthcare spending (around one tenth to one twelfth). Investments therefore contribute disproportionately to the footprint of non-metallic minerals and metals, highlighting the role of construction, renovation and capital equipment in driving material extraction.

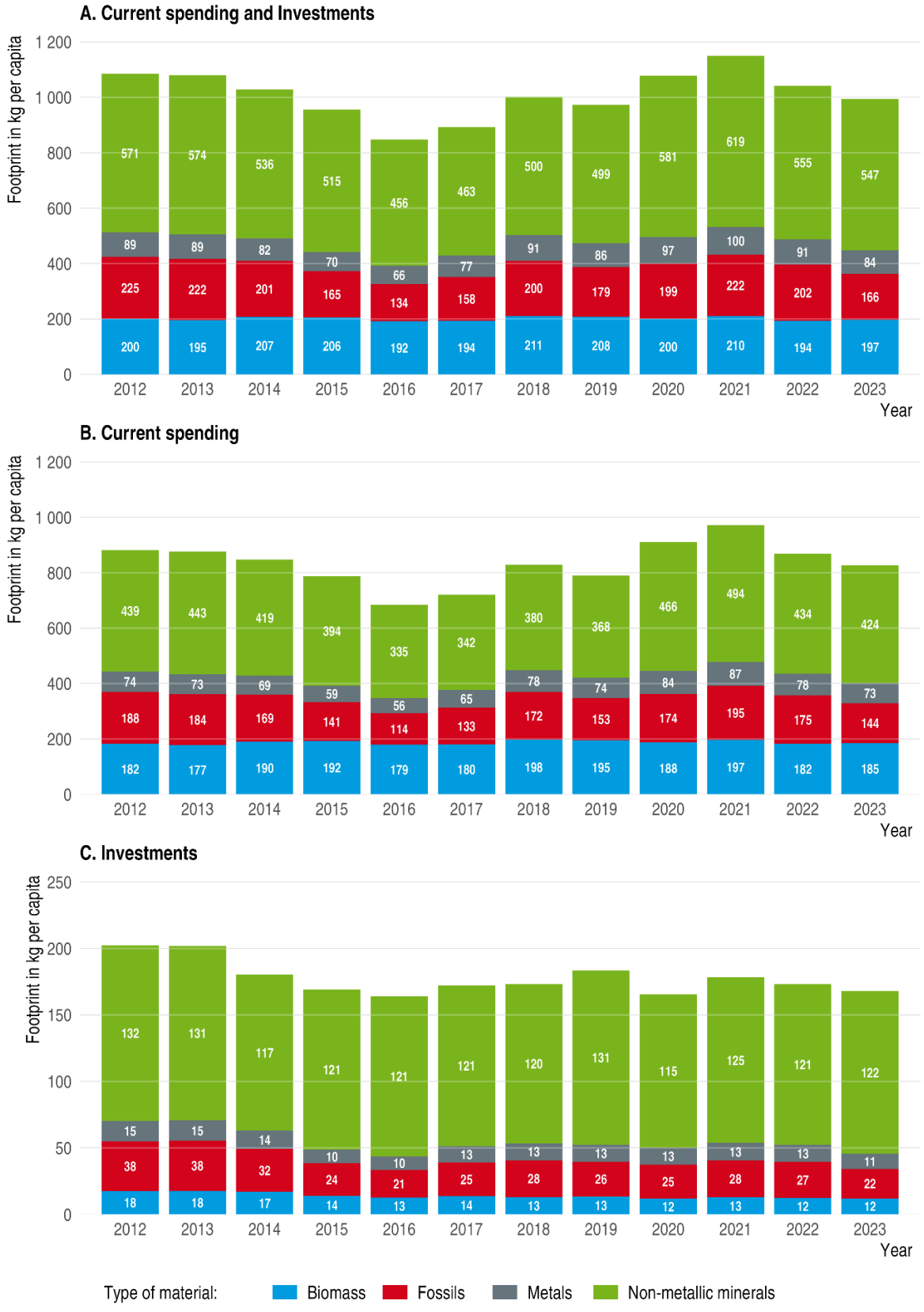
Table 1 – Annual material footprint of the health system by material type (in kg per capita and in kilotonne)

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	(2023*)
Results in kg per capita												
All materials	1 084	1 079	1 028	956	848	892	1 002	973	1 077	1 151	1 042	994
Biomass	200	195	207	206	192	194	211	208	200	210	194	197
Fossils	225	222	201	165	134	158	200	179	199	222	202	166
Metals	89	89	82	70	66	77	91	86	97	100	91	84
Non-metallic minerals	571	574	536	515	456	463	500	499	581	619	555	547
Results in kilotonne												
All materials	11 998	12 004	11 488	10 745	9 573	10 126	11 424	11 156	12 393	13 293	12 131	11 658
Biomass	2 210	2 171	2 318	2 316	2 167	2 198	2 404	2 390	2 300	2 424	2 262	2 307
Fossils	2 491	2 466	2 252	1 859	1 517	1 793	2 280	2 053	2 295	2 568	2 353	1 950
Metals	982	985	920	782	743	879	1 038	990	1 116	1 152	1 055	988
Non-metallic minerals	6 315	6 383	5 998	5 788	5 146	5 256	5 702	5 723	6 681	7 149	6 462	6 413

Source: VITO

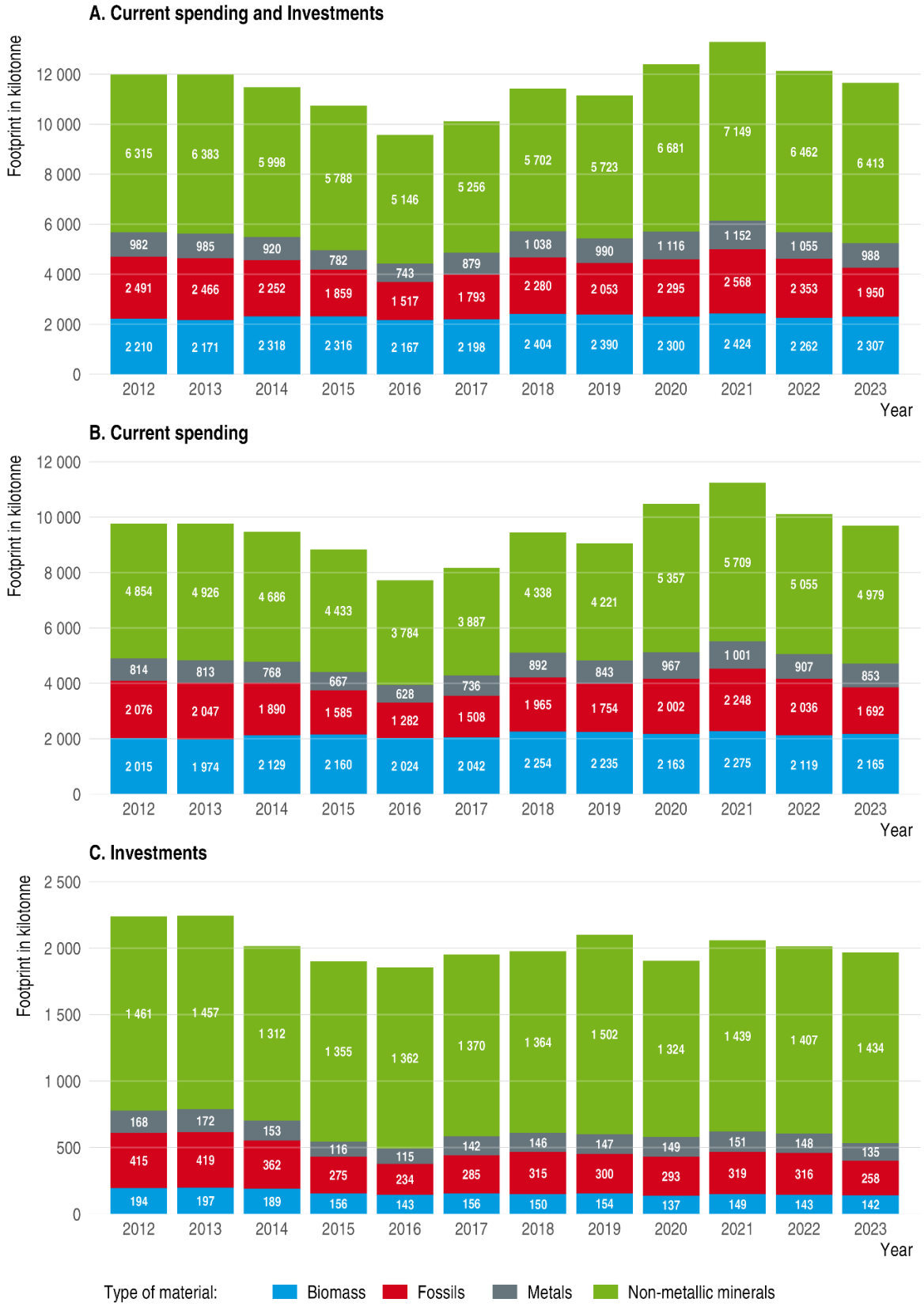
** 2023 results are preliminary and likely overestimated, as they are based on 2022 environmental intensities combined with 2023 monetary data without inflation adjustment. (see methodological note).*

Figure 1 – Annual material footprint of the health system by material type, subdivided by investment versus current spending (in kg per capita)



Source: VITO, Eurostat

Figure 2 – Annual material footprint of the health system by material type, subdivided by investment versus current spending (in kilotonne)

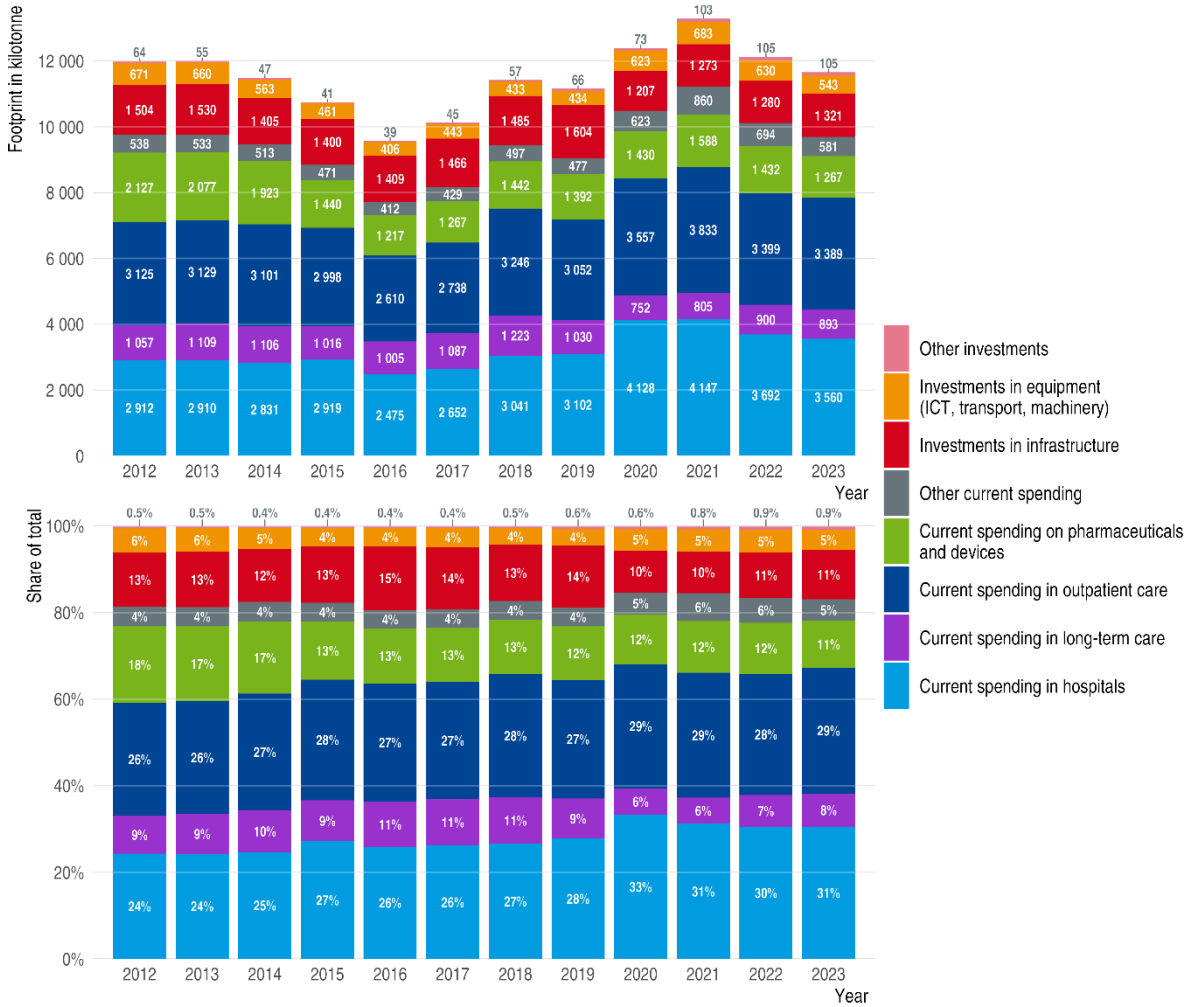


Source: VITO

ANALYSIS BY SPENDING CATEGORY

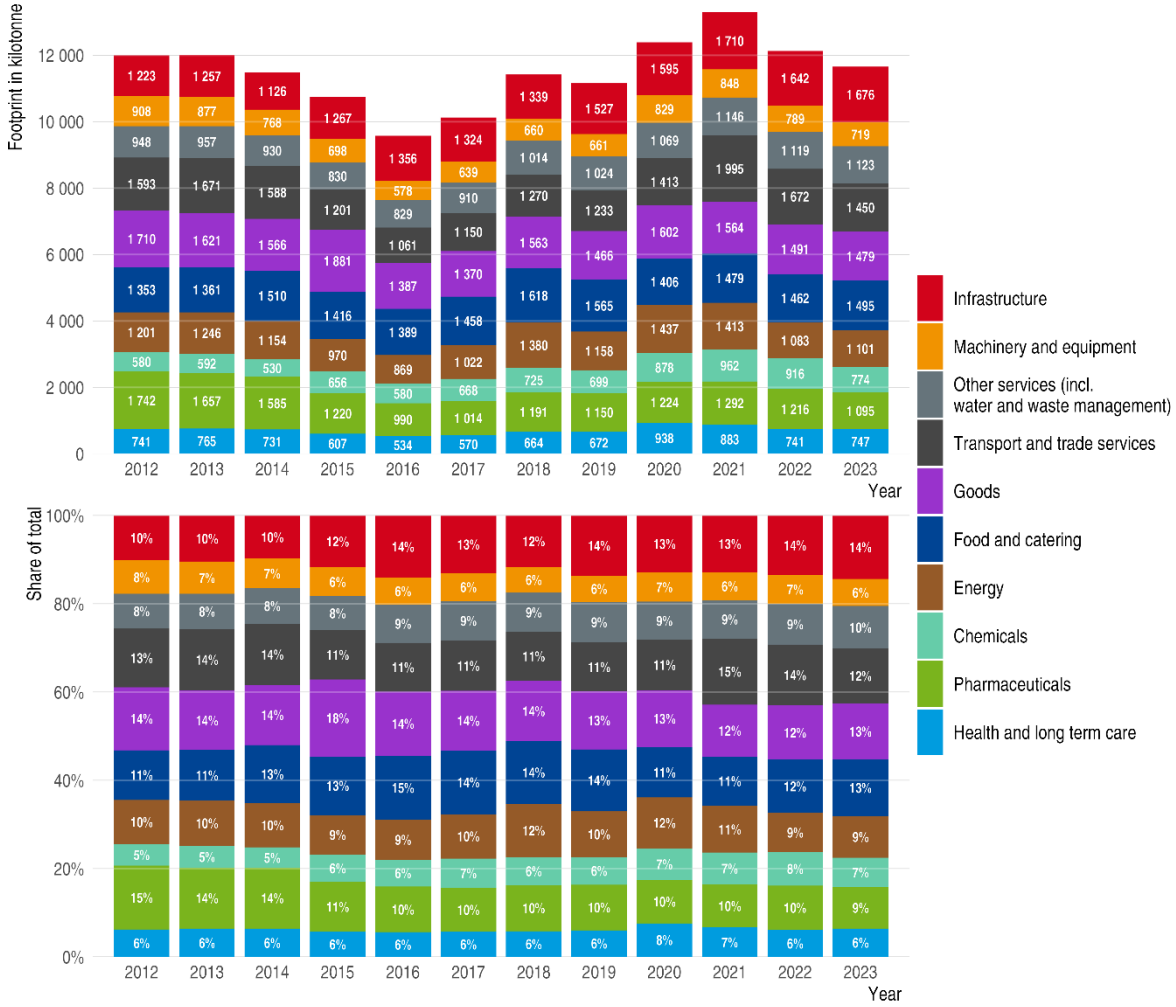
Figure 3 presents the material footprint of the health system over the period 2012-2023, disaggregated by current spending categories and investment types, and shown both in absolute terms (kilotonne) and as shares of the total footprint. The figure highlights where within the health system material use is generated. As indicated above, current spending dominates the material footprint in all years, accounting for approximately 80-85% of the total footprint. Hospital care and outpatient care together consistently represent around 50-60% of total material use. This primarily reflects their large share in overall healthcare spending and their central role in healthcare delivery. These spending categories are also closely associated with the COVID-related peak in material use. Pharmaceuticals and medical devices account for roughly 10-15% of the material footprint. Finally, investments generally represent around 15-20% of the total footprint. Within investments, infrastructure accounts for roughly two thirds of the impact, while equipment (including ICT, transport and machinery) accounts for about one third. This underlines the material intensity of construction and renovation in the health system.

Figure 3 – Annual material footprint of the health system by spending category (in kilotonne)



Source: VITO

Figure 4 – Annual material footprint of the health system by trigger product or service (in kilotonne)



Source: VITO

ANALYSIS BY TRIGGER PRODUCT OR SERVICE

Figure 4 and Figure 5 present the material footprint of the health system broken down by trigger product or service. Trigger products or services refer to the goods or services directly purchased by the healthcare sector that initiate upstream material extraction along supply chains in the input-output framework. This perspective complements the breakdown by spending category by identifying which types of goods and services directly initiate material use along global supply chains.

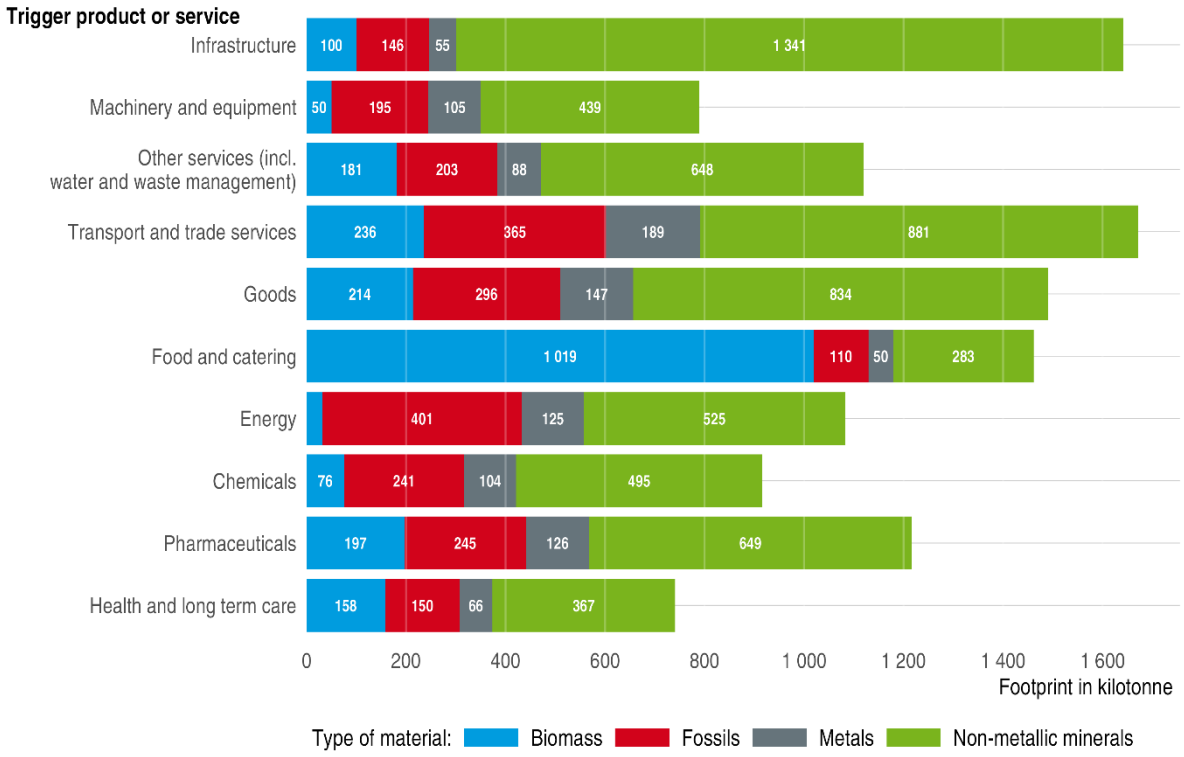
Figure 4 shows that the main contributors to the material footprint are infrastructure-related activities, goods, food and catering, transport and trade services, and pharmaceuticals, each accounting for shares consistently above 10% over the period 2012-2023. Over time, the most notable changes are a declining relative contribution of pharmaceuticals and an increasing contribution of infrastructure-related material use. The former appears to be linked to relatively limited growth in pharmaceutical spending between 2012 and 2020, resulting in a declining share within total healthcare expenditure. The latter is not explained solely by higher investment budgets (see Figure 3), but likely reflects current spending partly directed towards infrastructure-related goods and services.

These results highlight that a substantial share of the healthcare material footprint is driven not only by direct healthcare goods, such as pharmaceuticals and medical products, but also by enabling services,

including construction, transport, energy, food and supporting services, that underpin healthcare delivery.

Figure 5 provides a more detailed snapshot for 2022, illustrating how different trigger products and services are associated with distinct material profiles. Infrastructure and construction-related triggers are dominated by non-metallic minerals, reflecting the importance of construction materials such as concrete, or sand. Food and catering display high contributions from biomass. Fossil materials represent a large share of the material footprint for energy-related triggers, and to a lesser extent for transport and trade services, machinery and equipment, chemicals and pharmaceuticals. Other trigger categories show a more balanced mix of material types.

Figure 5 – Material footprint of the health system in 2022 broken down by trigger product or service and material type (in kilotonne)



Source: VITO
Note: No numeric labels are shown for material categories with values below 50 kilotonne.

STRUCTURE AND ORIGINS OF THE HEALTHCARE MATERIAL FOOTPRINT (2022)

Figure 6 presents the relative composition of the health system's material footprint in 2022, disaggregated by material type (A), spending category (B), trigger product or service (C), origin sector (D) and origin region (E).

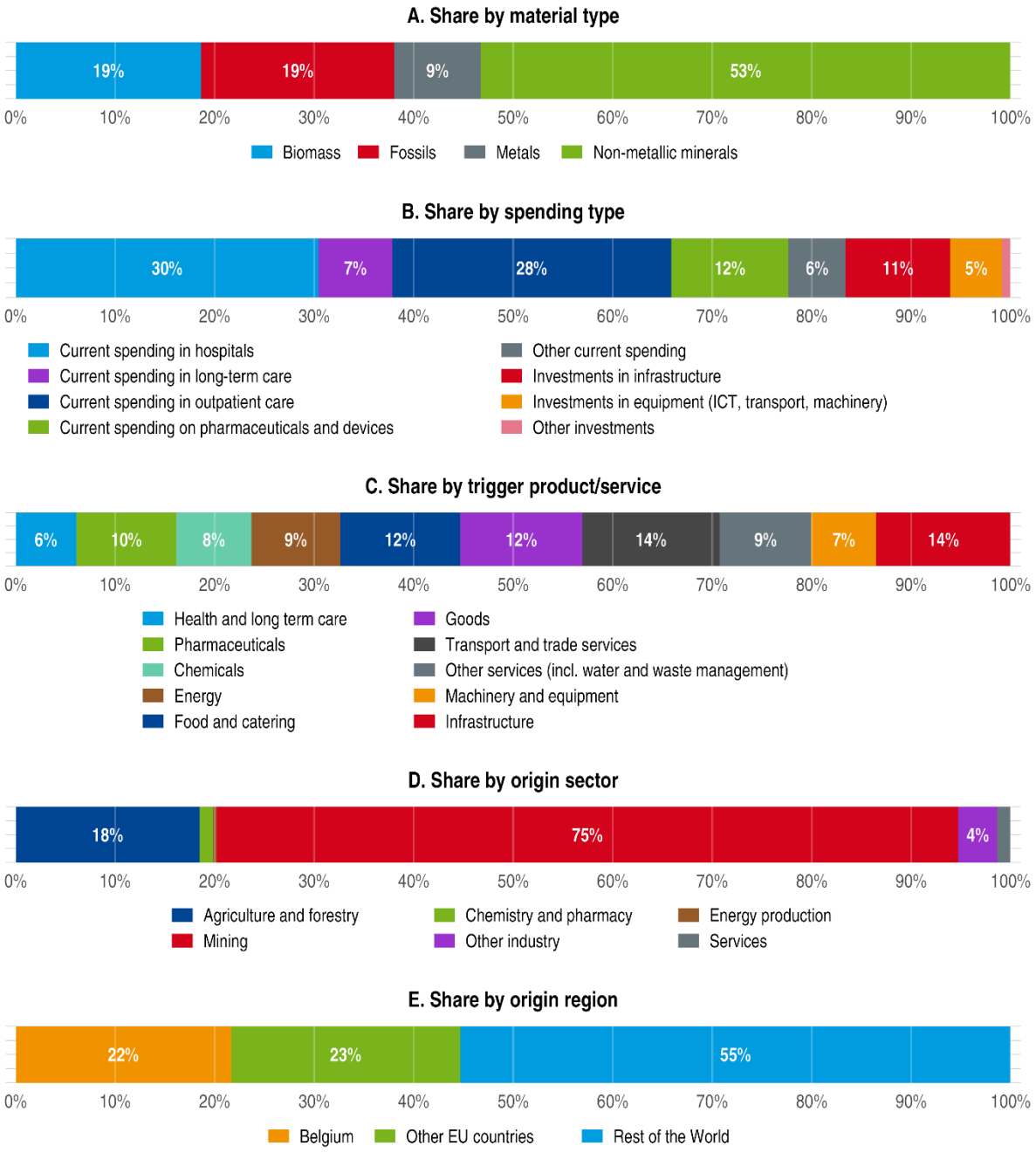
Panels A to C summarise patterns described in more detail above. In panel A, the material footprint is dominated by non-metallic minerals (53%), followed by biomass and fossil materials (each 19%), while metals account for a smaller share (9%). Panel B shows that current spending, in particular hospital and outpatient care, accounts for the majority of the footprint, with investments representing a smaller but relatively material-intensive share. Panel C confirms that the footprint is triggered not only by direct healthcare goods, such as pharmaceuticals and medical products, but also by enabling goods and services, including infrastructure, transport, energy, food and supporting services.

Panel D highlights the sectoral origin of material extraction underlying healthcare consumption. The footprint is overwhelmingly dominated by the mining sector, which accounts for approximately 75% of the total footprint in 2022, reflecting the importance of non-metallic minerals, metal ores and fossil

resources in healthcare supply chains. Agriculture and forestry contribute around 18%, mainly linked to biomass use, while other sectors play a minor role.

Panel E shows the geographical origin of material extraction. More than half of the healthcare material footprint (55% originates in the rest of the world, with other EU countries accounting for 23% and Belgium for 22%.This highlights the strong dependence of the health system on international supply chains for raw materials and intermediate goods, and illustrates that a substantial share of the environmental impact associated with Belgian healthcare consumption occurs outside national borders.

Figure 6 – Material footprint of the health system in 2022, relative shares by material type, spending category, trigger product or service, origin sector, and origin region



Source: VITO
Note: No numeric labels are shown for categories with shares below 2.5%.

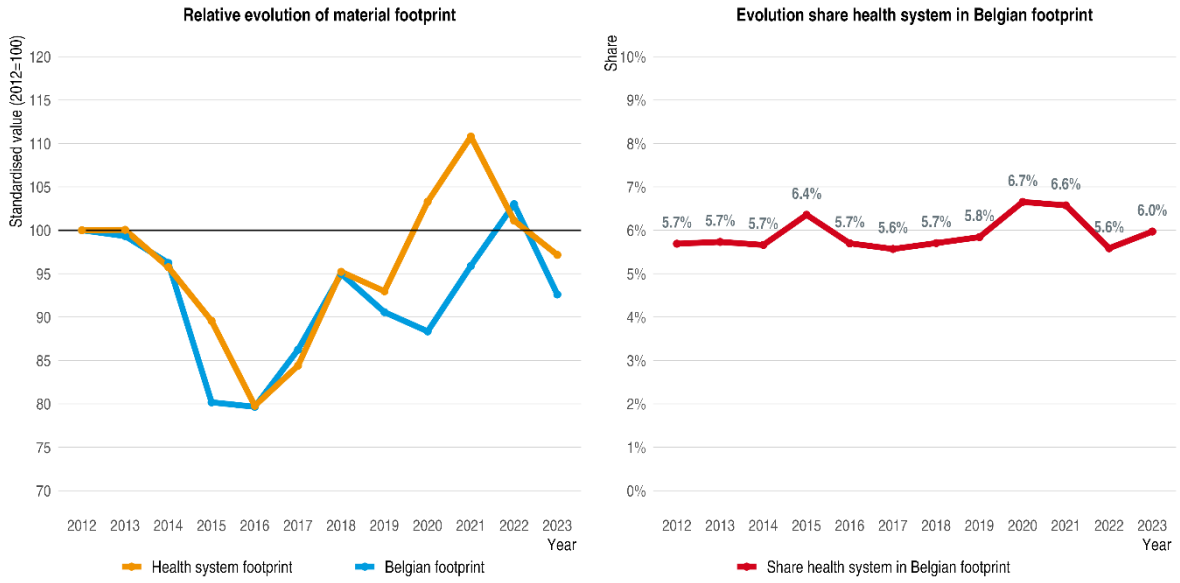
SHARE OF HEALTH SECTOR IN BELGIAN MATERIAL ENVIRONMENTAL FOOTPRINT

Figure 7 compares the relative evolution of the material footprint of the health system with that of the overall Belgian material footprint over the period 2012-2023 (left panel), with 2012 values standardised to 100, and shows the corresponding share of the health system in the Belgian material footprint (right panel).

The left panel indicates that both footprints follow a broadly similar trajectory, with a marked decline between 2012 and 2015 and even 2016 for the health system, followed by an increase between 2016 and 2018, which may partly reflect broader macroeconomic conditions including low interest rates that stimulated investment activity. During 2020-2021, a divergence emerges between the healthcare sector and the overall Belgian material footprint, associated with increased healthcare spending related to COVID-19, while other economic activities temporarily contracted. This was followed by a rebound in broader economic activity, with increased consumption and investment contributing to a peak in the Belgian material footprint in 2022. Subsequently, both footprints declined again, and by 2023 remained slightly below their 2012 levels, indicating that the reductions observed in the mid-2010s were not fully reversed.

The right panel shows that the share of the health system in the Belgian material footprint remains relatively stable over time, fluctuating within a narrow range of approximately 5.6% to 6.7%. A temporary increase is observed during 2020-2021, reflecting the comparatively stronger rise in healthcare-related material use during the pandemic.

Figure 7 – Relative evolution of the material footprint of the health system and Belgium since 2012 and evolution of the share of the health system in the Belgian material footprint



Source: VITO

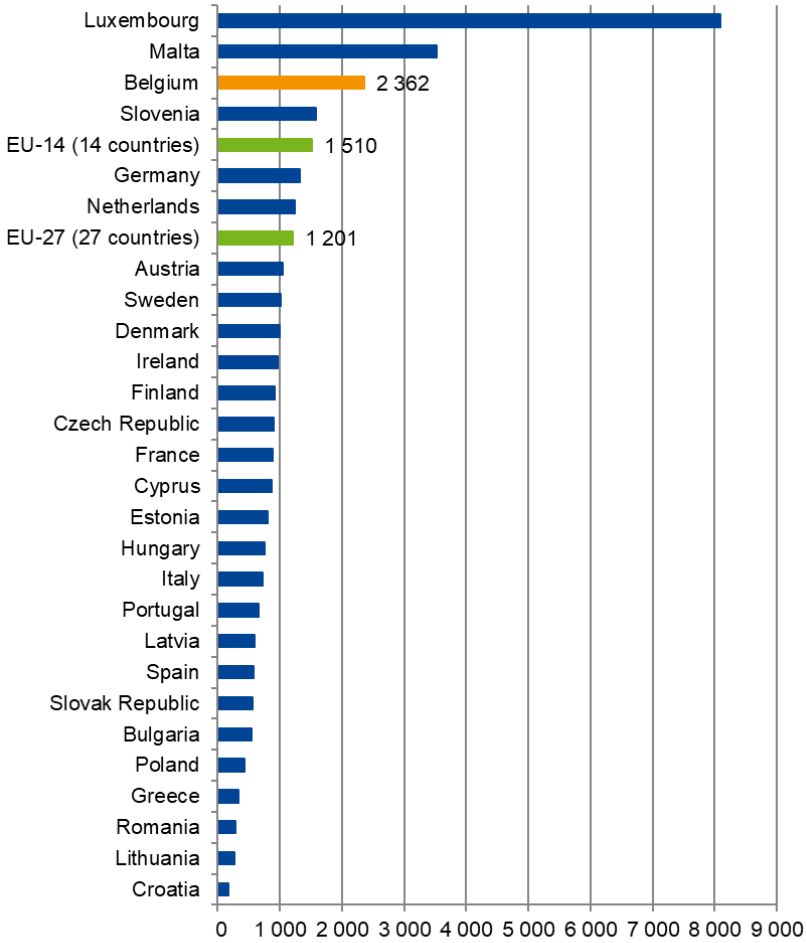
INTERNATIONAL COMPARISON

Figure 8 presents the material footprint of the healthcare sector across EU countries in 2015, expressed in kg per capita. The results are taken from Andrieu et al. (2023) and are based on the EXIOBASE EE-MRIO model (see technical definitions), which provides the most recent internationally comparable estimates available. [7] The Belgian estimates are approximately 2.5 times higher than those obtained using FIGARO – particularly for metals and non-metallic minerals – and are therefore not directly comparable with the primary and secondary indicators reported above. These differences reflect variations in model structure, sectoral aggregation, data sources and underlying assumptions.

Substantial variation is observed between countries. Belgium records a material footprint of 2 362 kg per capita, which is above both the EU-27 average (1 201 kg) and the EU-14 average (1 510 kg²),

placing Belgium among the higher-impact countries. Higher per-capita values are observed in a limited number of countries, notably Luxembourg and Malta, while most other EU Member States show lower per capita material footprints for the healthcare sector.

Figure 8 – Material footprint of the healthcare sector in 2015, international comparison (in kg per capita)



Source: Andrieu et al (2023), data 2015

KEY POINTS

- **The material footprint of the Belgian health system is around 1 000 kg per capita.** It ranged from 1 084 kg per capita (11 998 kt) in 2012 to 1 042 kg per capita (12 131 kt) in 2022. Despite growth in healthcare output, the absolute footprint in 2012 and 2022 is of similar magnitude, resulting in a slightly lower per-capita footprint in 2022.
- **Short-term variability reflects investment cycles and the COVID-19 shock.** Substantial variability is observed over time, with a decline between 2012-2016 followed by an increase broadly mirroring trends in the wider economy and partly linked to favourable investment conditions. The material footprint peaked in 2021 due to COVID-related surges in activity, followed by a partial decline but the mid-2010s reductions were not fully reversed by 2023.
- **The healthcare sector accounts for a stable share of the Belgian material footprint**. Abstracting from the COVID-19 period, the material footprint of the health system evolves broadly in line with that of the wider economy. The health system accounted for approximately 5.6% to

6.7% of the Belgian material footprint. A temporary increase during 2020-2021 reflects the sharper rise in healthcare-related material use compared with other sectors during the pandemic.

- **Non-metallic minerals dominate the healthcare material footprint.** They account for more than half of total material use, they are particularly predominant in infrastructure. Biomass, mainly linked to food and catering, and fossil energy carriers, particularly linked to energy use, transport and pharmaceuticals, each account for around one fifth, while metals play a smaller but stable role.
- **Current spending accounts for the majority of material use, but investments are highly material-intensive.** Current spending accounts for around **80-85%** of the material footprint, with hospital and outpatient care together responsible for more than half. Investments represent only a minor share of total spending but contribute around **one fifth to one sixth** of the footprint, confirming their high material intensity.
- **Material use is driven not only by healthcare goods but also by enabling services.** Trigger analysis shows that infrastructure-related activities, goods, food and catering, transport and trade services, and pharmaceuticals are the main initiators of upstream material extraction. This highlights the importance of construction, logistics, energy, food and supporting services in healthcare's material footprint and underscores the need for material efficiency and circularity across the entire supply chain.
- **Healthcare material use is largely driven by global extraction outside Belgium.** Around three quarters of material extraction originates in mining and about one fifth in agriculture and forestry. Only 22% of the footprint occurs in Belgium, with more than half generated outside the EU, underscoring strong dependence on international supply chains.
- **Belgium shows a high healthcare material footprint in international comparison.** In 2015 (the latest available internationally comparable data), Belgium recorded 2 362kg per capita, well above the EU-averages (EU-27: 1 201 kg, EU-14: 1 510 kg). These results are based on a different EE-MRIO model (EXIOBASE) and are therefore not directly comparable with the main analysis ; they should be interpreted as indicative only, as no more recent comparable data were identified.

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Methodological note on calculating the environmental footprint of the Belgian health system

Documentation sheet

Description	**Methodological description of the calculation of the environmental footprint of the Belgian health system. Relevant for indicators:** ENV-1 GHG environmental footprint of the healthcare sector ENV-2 Material environmental footprint of the healthcare sector ENV-3 Land environmental footprint of the healthcare sector
Rationale	Sustainable Development Goal (SDG) 12 aims to ensure sustainable consumption and production patterns, including environmental sustainability. **Environmental impact is inherently multi-dimensional.** The Planetary Boundaries framework formalises this multi-dimensionality by defining a safe operating space and assessing rising risks from human pressures on nine critical Earth-system processes.[1, 2] Life Cycle Assessment (LCA) – and the EU Environmental Footprint (EF) method derived from LCA – operationalises this systems view by quantifying potential impacts across multiple categories along full value chains, thereby capturing both direct and upstream burdens.[3-5] In this approach, environmental pressures and impacts span not only greenhouse gas emissions, but also particulate matter and photochemical ozone formation, acidification, land occupation and transformation, resource use, blue water consumption, waste generation, and chemical pollution and ecotoxicity (e.g. pharmaceutical residues in surface waters). The EF approach allows the calculation of environmental impacts for products and services, sectors, or countries while explicitly accounting for trade-offs and potential burden shifting across impact categories or geographies. Several of these dimensions are reflected in the broader SDG framework (e.g. SDG 6 Clean Water and Sanitation; SDG 7 Affordable and Clean Energy; SDG 13 Climate Action; SDG 14 Life Below Water; SDG 15 Life on Land). The SDG agenda, while structured as individual goals, is designed with interlinkages and spillovers, implying that environmental sustainability can only be addressed by balancing environmental, social and economic objectives.[6] **Evidence indicates that humanity has already exceeded safe limits** for multiple planetary boundaries, not only climate.[1, 7] In an assessment linking life-cycle impact indicators to planetary boundaries, Sala et al. (2020) found that environmental impacts of EU consumption were close to, or transgressing, boundaries for climate change, particulate matter, land use and mineral resources.[4] Research also shows that the environmental footprint of the healthcare sector is substantial. Because healthcare represents a sizeable share of economic activity and final demand, its environmental footprint can be large even when impact intensities per euro of expenditure are moderate compared with more impact-intensive economic activites.[3] International studies estimate that healthcare contributes a meaningful share of national and global environmental burdens across multiple indicators, representing around 2-7% of the GHG footprint in OECD countries;[8-10] 7% of global non-metallic minerals footprint and 4% of global metal ores footprint;[11] 2-7% of SO_2, 1-6% of blue water and 2-8% of PM-footprint in a subset of countries.[10] Estimates vary by country and method, and national studies can yield higher values when using detailed national expenditure and emissions data.[7, 12] **Healthcare impacts arise directly from operations and indirectly through upstream supply chains** through the goods and services supplied to health systems**.** The indirect impact is often the largest component, representing around 60-80% of healthcare-related GHG emissions.[8, 13, 14] This supports an environmental footprint approach using environmentally extended input-output (EE-IO/MRIO) methods, which link health expenditures to the multiple environmental impacts embodied in the goods and services the sector consumes and produces and enable identification of supply-chain hotspots.[12] **A multi-category environmental footprint is not only diagnostic; it is also actionable**. The health-care sector can make a contribution towards reducing environmental harm.[14] It can inform on the potential of strategies such as reducing fossil energy dependence,

	improving resource efficiency, and advancing circularity in procurement and service delivery, while enabling monitoring over time and safeguarding against unintended trade-offs across impact categories.[13]
Calculation	The environmental footprints for the Belgian healthcare system are estimated using a top-down **Environmentally Extended Multi-Regional Input-Output (EE-MRIO)** approach. The method consists of **three main steps (**See technical definitions below for more details). **1. Constructing the healthcare final demand vector.** Detailed health expenditure data by provider type and function from the System of Health Accounts (SHA), together with sectoral investment data from the national accounts, are combined to represent total monetary demand for healthcare goods, services and capital formation in Belgium. **2. Mapping the full supply chain using input-output analysis.** Input-output analysis links this final demand to all domestic and international industries involved to produce the necessary goods and services required for the health system to function. Using input-output tables, it traces both direct healthcare activity and indirect activity embodied in intermediate goods across global supply chains. **3. Linking monetary flows to environmental extensions.** Monetary flows are then matched to environmental extension tables, which contain sector-specific environmental impact intensities. This allows calculation of the direct and indirect environmental impacts associated with healthcare consumption, and distinguishes between domestic and imported contributions. This approach follows established methodologies used in previous healthcare footprint studies.[8-12, 15] However, results may differ due to, amongst others, differences in input data, assumptions regarding the composition of healthcare final demand, sectoral resolution, and the environmental extensions used. The analysis uses the **FIGARO EE-MRIO database** (2025 edition, developed by Eurostat/JRC), covering 64 industries (NACE Rev.2) across the EU-27 and 18 non-EU countries plus a “rest of world” region (country-resolution matched to earlier FIGARO editions). The IO tables are benchmarked to official macroeconomic aggregates and follow the same quality standards as other official EU statistics. Environmental extensions draw on Eurostat Air Emission Accounts and additional environmental impact intensities derived from EXIOBASE v3.8.2 by VITO.[16, 17] **Impact categories** include climate change, particulate matter formation, photochemical ozone formation, acidification, ecotoxicity, blue water consumption, material extraction and land use. Gross value added is also assessed to show how economic value is distributed along global healthcare supply chains.
Data source	Current health expenditure and financing data from the System of Health Accounts (2010-2023).[18, 19] Capital investment data from Eurostat [nama_10_a64_p5] (NACE Q86 and Q87-88). [20] FIGARO annual input-output tables 2010-2023 [21] Environmental extension tables based on environmental extension lines from EXIOBASE v3.8.2[16] and supplemented by VITO with Eurostat Air Emission Accounts data [env_ac_ainah_r2][17] (CO_2, N_2O, HFC, PFC, CH_4, CO, NMVOC, NOX, NH_3, PM10, PM2.5). Extension data of 2022 were used as proxy for 2023.
Technical definitions	**Input-output analysis** The environmental impact of the health sector has been calculated using an extended multiregional input-output model based on FIGARO (industry-by-industry tables). The calculation is based on the following formula: $$E^T_{ind,health} + E^T_{dir,health} = \langle e^{int} \rangle . x + E^T_{dir,health} = \langle e^{int} \rangle . L . y_{health} + E^T_{dir,health}$$ with: • $E^T_{ind,health}$: environmental footprint – indirect environmental impacts embodied in upstream supply chains for healthcare final demand

- $E^{T}_{dir,health}$: environmental footprint – direct environmental impacts generated by the healthcare sector itself
- $\langle e^{int} \rangle$: environmental impact intensity vector, the impact directly caused per unit of sectoral monetary output
- x: vector of sectoral monetary output
- L Leontief inverse, representing the economic structure of global supply chains
- y_{health}: final demand vector for healthcare goods, services and investments

The scope includes both indirect and direct impacts. Indirect impacts represent all upstream environmental pressures occurring in the global production network, e.g. manufacturing of pharmaceuticals and medical devices, agricultural inputs, energy production, construction, and transport. Direct impacts represent environmental pressures generated by the healthcare sector itself, such as on-site fuel combustion for heating, or fuel use for ambulance fleets.

Applying the formula yields one result – one footprint value – for each environmental impact category included in the calculation (see below). This represents the total (direct + indirect) environmental impact associated with healthcare final demand. To obtain more detailed results, diagonalisation can be applied:

- Diagonalising the environmental intensity vector produces allows attribution of impacts to the origin sectors and regions/country in which they occur.
- Diagonalising the final demand vector produces a diagonal matrix that enables attribution of impacts to the trigger products and services, i.e. products and services consumed by the health system by region/country that trigger the environmental impact
- Diagonalising both the environmental intensity vector and the final demand vector yields a full origin × trigger matrix, detailing both where impacts occur and which healthcare-related consumption cause them.

For a detailed discussion of the theoretical background and mathematical properties of IO models, see the foundational work of Leontief and Miller & Blair.[22, 23]

Environmental impact categories

The following environmental impact categories in the environmental footprint method are included (Table 2).

Table 2 – overview and description environmental impact categories

Climate Change	kg CO2-eq	Global impact due to changes induced to the climate, including increased average global temperatures and sudden regional climatic changes, as a consequence of the emissions to the atmosphere of the so-called greenhouse gases, such as CO2, CH4, and N2O.
Particulate Matter (PM)	disease inc.	Impact on human health due to the increased ambient concentrations of particulate matter (PM) due to the emissions of primary and secondary particulates (i.e. precursors, NOx, SO2).
PM10	kg	Emissions to air of particulate matter contains a mixture of solid particles and liquid droplets. Particles are defined by their diameter for air quality regulatory purposes. Those with a diameter of 10 microns or less (PM10) are inhalable into the lungs and can induce adverse health effects. Fine particulate matter is defined as particles that are 2.5 microns or less in diameter (PM2.5). Therefore, PM2.5 comprises a portion of PM10.
PM2.5	kg	
Photochemical Ozone Formation	kg NMVOC eq.	Local and regional impact to the environment and human health related to the formation of tropospheric ozone resulting from the oxidation of solvents and other volatile organic compounds (VOCs) released to the atmosphere that affects organic compounds in animals and plants and can increase the frequency of respiratory problems.
Acidification	mol H+ eq. and SO_2-eq.	Regional impact to the environment regarding the modification of acidity of soils, as consequences of emission and deposition of acids (and compounds that can be converted to acids) into the environment. Includes SO_2, NH_3, NO_2

Land Use	Pt and km²	Impacts because of occupation and transformation of land in terms of reduction of soil qualities (e.g. modification in the organic matter content of soil, or loss of the soil itself (erosion)). The indicator includes cropland, forest area, permanent pastures, infrastructure land, and other land use.
Ecotoxicity freshwater	CTUe	Local and regional impact to freshwater ecosystem due to the release of toxic substances that can accumulate and affect individual species as well as the functioning of the entire ecosystem.
Water Use	m3 depriv. and m³	Impact related to the consumption of freshwater (lakes, rivers, or groundwater)
Resource Use, fossils	MJ	Global impact related to the decreased availability and the potential scarcity for future generations of the total reserve of fossil resources.
Resource Use, minerals and metals	kg Sb eq.	Global impact related to the decreased availability and the potential scarcity for future generations of the total reserve of mineral and metal resources.
FOSSIL, BIOMASS, METALS, MINERALS, Resource use or primary material footprint	kg	Resource use or primary material footprint, split into biomass, non-metallic minerals, metal ores, and fossil energy carriers.
Gross value added	Million euros	The gross value-added indicator shows the global distribution of value added generated across sectors. The indicator shows the economics of the upstream supply network of the Belgian health sector. This is mainly with a more illustrative purpose to understand the functioning of the model.

Construction of a healthcare final demand vector

To construct a healthcare final demand vector, we follow the methodology developed by the OECD and RIVM.[7, 8, 12] This vector represents the final demand for healthcare goods and services and is the input for a next step to calculate the environmental impact of this sector. The following steps are followed:

1. **Data**. Belgian current health expenditure data (SHA, 2010–2023, million EUR, current prices) by function (HC) and provider (HP) are extracted from the OECD database.[18, 19]
   Investment expenditures are taken from Eurostat national accounts for sector Q86 - human health activities.[20]
2. **Compilation of expenditure categories.** Except for pharmaceutical and medical devices, all current spending retain provider-level detail. This gives the following subcategories:
   - Pharmaceuticals/OTC medicines (HC.5.1.1+HC.5.1.2)
   - Medical non-durables and devices (HC.5.1.3+HC.5.2)
   - Other current healthcare expenditure (total per HF minus HC.5): general hospitals (HP.1.1), mental health hospitals (HP.1.2), specialised hospitals (HP.1.3), long-term nursing care facilities (HP.2.1), mental health and substance abuse facilities (HP.2.2), other residential long-term care facilities (HP.2.9), medical practices (HP.3.1), dental practices (HP.3.2), other health care practitioners (HP.3.3), ambulatory health care centres (HP.3.4), providers of home health care services (HP.3.5), providers of patient transportation and emergency rescue (HP.4.1), medical and diagnostic laboratories (HP.4.2), other providers of ancillary services (HP.4.9), pharmaceuticals (HP.5.1), medical devices and therapeutical appliances (HP.5.2), all other miscellaneous sellers and other suppliers of pharmaceuticals and medical goods (HP.5.9), providers of preventive care (HP.6), government health administration agencies (HP.7.1), social health insurance agencies (HP.7.2), private health insurance administration agencies (HP.7.3), other administration agencies (HP.7.9), households as providers of home health care (HP.8.1), all other industries as secondary providers of health care (HP.8.2)

- Investments by asset type: infrastructure (N11KG), transport equipment (N1131G), ICT equipment (N1132G), other equipment (N11OG), computer software and databases (N1173G), intellectual property products not elsewhere classified (N117G)

3. **Mapping to FIGARO sectors**. Each expenditure category is mapped to the industry classification of FIGARO. This mapping determines how each euro of healthcare spending is disaggregated into the goods and services used in production. The input structure of this FIGARO sector (its purchases from other sectors) is then used to distribute healthcare spending across the domestic and international supply chain. Choosing an appropriate proxy sector is important, as this structure determines how spending is translated into upstream economic activity and, subsequently, environmental impacts.
   - Pharmaceuticals/OTC medicines: sector C21 (pharmaceutical manufacturing)
   - Medical non-durables and devices: sector C26 (optical/electronic products)
   - Other expenditures: see correspondence Table 3. Because pharmaceuticals are allocated directly to C21, this sector is excluded from the input structure used to disaggregate the remaining ("other") healthcare expenditures to avoid double counting. The same adjustment is not applied to C26, as this sector covers a broader range of products beyond medical devices.

Table 3 – Correspondence current health expenditure HP subcategories and Figaro industry classification

Healthcare provider	Corresponding NACE-sector (FIGARO-classification)	
HP.1.1 General hospitals	Q86	Human health activities
HP.1.2 Mental health hospitals	Q86	Human health activities
HP.1.3 Specialised hospitals (other than mental health hospitals)	Q86	Human health activities
HP.2.1 Long-term nursing care facilities	Q87_88	Residential care activities and social work activities without accommodation
HP.2.2 Mental health and substance abuse facilities	Q87_88	Residential care activities and social work activities without accommodation
HP.2.9 Other residential long-term care facilities	Q87_88	Residential care activities and social work activities without accommodation
HP.3.1 Medical practices	Q86	Human health activities
HP.3.2 Dental practices	Q86	Human health activities
HP.3.3 Other health care practitioners	Q86	Human health activities
HP.3.4 Ambulatory health care centres	Q86	Human health activities
HP.3.5 Providers of home health care services	Q86	Human health activities
HP.4.1 Providers of patient transportation and emergency rescue	Q86	Human health activities
HP.4.2 Medical and diagnostic laboratories	Q86	Human health activities
HP.4.9 Other providers of ancillary services	Q86	Human health activities
HP.5.1 Pharmaceuticals	Q86	Human health activities (for remaining values only)
HP.5.2 Medical devices and therapeutical appliances	Q86	Human health activities (for remaining values only)
HP.5.9 All other miscellaneous sellers and other suppliers of pharmaceuticals and medical goods	Q86	Human health activities (for remaining values only)
HP.6 Providers of preventive care	O84	Public administration and defence; compulsory social security

HP.7.1 Government health administration agencies	O84	Public administration and defence; compulsory social security
HP.7.2 Social health insurance agencies	O84	Public administration and defence; compulsory social security
HP.7.3 Private health insurance administration agencies	K65	Insurance, reinsurance and pension funding, except compulsory social security
HP.7.9 Other administration agencies	O84	Public administration and defence; compulsory social security
HP.8.1 Households as providers of home health care	Q86	Human health activities
HP.8.2 All other industries as secondary providers of health care	O84	Public administration and defence; compulsory social security

- Investments by asset type: see correspondence Table 4.

Table 4 – Correspondence investment subcategories and Figaro industry classification

Gross fixed capital formation by asset type		Corresponding NACE-sector (FIGARO-classification)	
N11KG	Total construction (gross)	F	Construction
N1131G	Transport equipment (gross)	C29	Manufacture of motor vehicles, trailers and semi-trailers
N1132G	ICT equipment (gross)	C26	Manufacture of computer, electronic and optical products
N11OG	Other machinery and equipment (gross)	C28	Manufacture of machinery and equipment n.e.c.
N117G	Intellectual property products (gross)	M72	Scientific research and development
N1173G	Computer software and databases (gross)	J62_63	Computer programming, consultancy, and information service activities

4. **Conversion to basic prices**. Health expenditure data reported in **purchaser prices** are converted into basic prices, trade & transport margins, and taxes/subsidies using data on the Belgian sector human health activities (Q86) from Eurostat use tables at purchaser prices [nama_10_cp16], the use table at basic prices [nama_10_cp1610], the table of trade and transport margins [naio_10_cp1620], and the table of taxes less subsidies on products [naio_10_cp1630]. For each product a conversion factor is calculated as the share of the basic price/trade and transport margins in the purchaser price over the whole period (only using years 2010-2023 for which the database is complete). These factors are provided in Table 5.
   Only basic prices and trade & transport margins are retained for further analysis. The trade and transport margins are directly allocated to wholesale trade (sector G46).

Table 5 – Correspondence expenditure subcategories and factors for basic prices, trade and transport margins, and taxes less subsidies

Expenditure category	Basic price	Trade & transport	Taxes less subsidies
Service sectors (K65, O84, Q86, Q87-88)	1.000	0.000	0.000
Pharmaceuticals & OTC (HC.5.1.1 + HC.5.1.2)	0.764	0.163	0.073
Medical non-durables & devices (HC.5.1.3 + HC.5.2)	0.450	0.376	0.174
Investment in construction, computer software and databases, intellectual property products	1.000	0.000	0.000
Investment in transport equipment	0.713	0.108	0.179
Investment in ICT equipment	0.450	0.376	0.174

Investment in other equipment	0.428	0.398	0.174

5. **Geographic allocation.** Spending on each product is allocated across countries using FIGARO's regional production shares, distinguishing domestic from foreign production.

Model output structure

The analysis produces two complementary outputs: a **longitudinal series** covering 2010-2023 and a **cross-sectional decomposition** providing a higher level of detail for 2022. Environmental impact data for 2023 were not yet available; therefore, preliminary results for that year were estimated by combining 2022 environmental intensities with 2023 monetary data. As no adjustment for inflation was applied, these preliminary estimates for 2023 are likely to overstate environmental impacts. For this reason, 2022 was selected as the reference year for the cross-sectional decomposition.

The **longitudinal results** provide, for each year and each environmental impact category, the total footprint of Belgian healthcare sector, further subdivided by type of spending (the subcategories of the healthcare final demand vector described above), by trigger product or service, representing the product or service directly consumed by the healthcare sector (see Table 6 for an overview of the triggers), and by region in which the impacts occur (aggregated into Belgium, the rest of the EU-27 and the rest of the world). These results illustrate how the environmental footprint evolves over time and how different components of the health system contribute to it. In the longitudinal series, the origin of impacts is not further disaggregated.

The **cross-sectional results** for 2022 contain the same subdivisions but add an additional level of structural detail by identifying the sector group in which impacts originate. This enables a trigger–origin analysis, showing which healthcare consumption categories drive environmental pressures and which sectors and regions in the global production network generate those impacts. Table 6 below provides an overview of the structure of origin sector groups.

Table 6 – Allocation of sectors in FIGARO to trigger product and services and origin sector groups

Industries (NACE Rev.2)		Trigger categories	Origin sector categories
Code	Label		
A01	Crop and animal production, hunting and related service activities	Food and catering	Agriculture and forestry
A02	Forestry and logging	Infrastructure	Agriculture and forestry
A03	Fishing and aquaculture	Food and catering	Agriculture and forestry
B	Mining and quarrying	Infrastructure	Mining
C10T12	Manufacture of food products; beverages and tobacco products	Food and catering	Other industry
C13T15	Manufacture of textiles, wearing apparel, leather and related products	Goods	Other industry
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	Infrastructure	Other industry
C17	Manufacture of paper and paper products	Goods	Other industry
C18	Printing and reproduction of recorded media	Goods	Other industry
C19	Manufacture of coke and refined petroleum products	Energy	Energy production
C20	Manufacture of chemicals and chemical products	Chemicals	Chemistry and pharmacy
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	Pharmaceuticals	Chemistry and pharmacy

C22	Manufacture of rubber and plastic products	Goods	Other industry
C23	Manufacture of other non-metallic mineral products	Goods	Other industry
C24	Manufacture of basic metals	Goods	Other industry
C25	Manufacture of fabricated metal products, except machinery and equipment	Machinery and equipment	Other industry
C26	Manufacture of computer, electronic and optical products	Machinery and equipment	Other industry
C27	Manufacture of electrical equipment	Machinery and equipment	Other industry
C28	Manufacture of machinery and equipment n.e.c.	Machinery and equipment	Other industry
C29	Manufacture of motor vehicles, trailers and semi-trailers	Transport and trade services	Other industry
C30	Manufacture of other transport equipment	Transport and trade services	Other industry
C31_32	Manufacture of furniture; other manufacturing	Goods	Other industry
C33	Repair and installation of machinery and equipment	Machinery and equipment	Other industry
D35	Electricity, gas, steam and air conditioning supply	Energy	Energy production
E36	Water collection, treatment and supply	Water and waste management	Other industry
E37T39	Sewerage, waste management, remediation activities	Water and waste management	Other industry
F	Construction	Infrastructure	Other industry
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles	Transport and trade services	Services
G46	Wholesale trade, except of motor vehicles and motorcycles	Transport and trade services	Services
G47	Retail trade, except of motor vehicles and motorcycles	Transport and trade services	Services
H49	Land transport and transport via pipelines	Transport and trade services	Services
H50	Water transport	Transport and trade services	Services
H51	Air transport	Transport and trade services	Services
H52	Warehousing and support activities for transportation	Transport and trade services	Services
H53	Postal and courier activities	Transport and trade services	Services
I	Accommodation and food service activities	Food and catering	Services
J58	Publishing activities	Services	Services
J59_60	Motion picture, video, television programme production; programming and broadcasting activities	Services	Services
J61	Telecommunications	Services	Services
J62_63	Computer programming, consultancy, and information service activities	Services	Services
K64	Financial service activities, except insurance and pension funding	Services	Services
K65	Insurance, reinsurance and pension funding, except compulsory social security	Services	Services

	K66	Activities auxiliary to financial services and insurance activities	Services	Services
	L	Real estate activities	Infrastructure	Services
	M69_70	Legal and accounting activities; activities of head offices; management consultancy activities	Services	Services
	M71	Architectural and engineering activities; technical testing and analysis	Services	Services
	M72	Scientific research and development	Services	Services
	M73	Advertising and market research	Services	Services
	M74_75	Other professional, scientific and technical activities; veterinary activities	Services	Services
	N77	Rental and leasing activities	Services	Services
	N78	Employment activities	Services	Services
	N79	Travel agency, tour operator and other reservation service and related activities	Transport and trade services	Services
	N80T82	Security and investigation, service and landscape, office administrative and support activities	Services	Services
	O84	Public administration and defence; compulsory social security	Services	Services
	P85	Education	Services	Services
	Q86	Human health activities	Medical products and services	Direct impacts
	Q87_88	Residential care activities and social work activities without accommodation	Long term care	Direct impacts
	R90T92	Creative, arts and entertainment activities; libraries, archives, museums and other cultural activities; gambling and betting activities	Services	Services
	R93	Sports activities and amusement and recreation activities	Services	Services
	S94	Activities of membership organisations	Services	Services
	S95	Repair of computers and personal and household goods	Services	Services
	S96	Other personal service activities	Services	Services
	T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	Services	Services
	U	Activities of extraterritorial organisations and bodies	Services	Services

International comparability	The model produces results only for Belgium. While several countries have developed healthcare environmental footprints, differences in EE-MRIO models, sector classifications, health expenditure definitions, environmental extensions, and methodological assumptions mean that results are not directly comparable across model frameworks.
Limitations	**Model- and assumption-dependence.** Results depend on the specific EE-MRIO system used, the environmental extensions applied, the mapping of expenditures to sectors, and other underlying modelling assumptions. Different EE-MRIO frameworks can therefore yield different footprint estimates. **Sectoral aggregation.** FIGARO provides 64 sector categories. Sectoral aggregation limits the ability to capture fine-grained variations in upstream impacts. Nevertheless, FIGARO includes a dedicated pharmaceutical sector (C21), which improves the accuracy of pharmaceutical-related impacts in comparison to other MRIO systems, such as EXIOBASE, where pharmaceuticals are grouped with a broader “chemicals n.e.c.” category that yields less precise estimates for healthcare-relevant supply chains. **Uniform environmental impact intensities across provider types.** While the healthcare final demand vector is detailed, several current spending categories are

	ultimately mapped to the same FIGARO healthcare sector (Q86). As a result, the model applies identical supply-chain structures and environmental impact intensities to hospitals and outpatient providers. Hence, the model cannot distinguish environmental impact generated by one euro of spending in hospitals or outpatient providers. **Limited representation of healthcare-specific sources.** The IO analysis is a top-down, expenditure-driven approach and is not complemented with detailed bottom-up healthcare data. Consequently, emissions from sources such as anaesthetic gases, staff travel, on-site energy choices, or renewable energy procurement are not necessarily fully captured. **Household consumption impacts not fully represented.** The analysis captures environmental impact from industries, not from households. Therefore, household-level impacts related to healthcare, such as patient travel are not included. **Direct impact of certain impact categories.** Some impact categories are not fully aligned with the specifics of the healthcare sector. For example, the environmental-footprint (EF) land-use indicator is dominated by agricultural land occupation, while infrastructure land associated with hospital buildings and other healthcare infrastructure is not captured directly and cannot be isolated explicitly. **Potential overestimation of environmental impacts in 2023.** Environmental impact data for 2023 were not yet available. As a result, preliminary 2023 estimates were derived by applying 2022 environmental intensities to 2023 monetary data without inflation adjustment. These estimates are therefore likely to overstate environmental impacts, and 2022 was retained as the reference year for detailed structural analysis.
Dimension	Environmental sustainability
Related indicators	ENV-1 GHG environmental footprint of the healthcare sector ENV-2 Material environmental footprint of the healthcare sector ENV-3 Land environmental footprint of the healthcare sector ENV-5 Particulate matter environmental footprint of the healthcare sector (PM 2.5; PM10) ENV-6 acidifying gas environmental footprint of the healthcare sector ENV-7 Ozone precursor environmental footprint of the healthcare sector
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