1 OVERALL ENVIRONMENTAL FOOTPRINT OF THE HEALTH SYSTEM

1.3 Land use environmental footprint of the healthcare sector (ENV-3)

1.3.1 Documentation sheet

Description	**Primary indicator**: A. Annual land use environmental footprint of the healthcare sector, in m² per capita **Secondary indicator(s):** B. Annual land use environmental footprint of the healthcare sector, in million Pt per capita C. Annual land use environmental footprint of the healthcare sector, in km² D. Annual land use environmental footprint of the healthcare sector, as a share of total land use 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, food provision in hospitals and care facilities, medical textiles, pharmaceuticals and other goods and services, all of which rely directly or indirectly on land resources at some stage. Land is a finite and scarce resource that serves multiple competing societal functions. Since the 1960s, growth in global population and consumption has substantially accelerated land use, pushing land systems further into a zone of increasing environmental risk. [4]Today, around half of the world's ice- and desert-free land is used for agriculture, illustrating the scale of human pressure on terrestrial ecosystems. [5] Land-use change and land occupation linked to biomass production are among the main drivers of biodiversity loss, soil degradation and ecosystem disruption. [4-8] Converting natural ecosystems into cropland, pasture, forest plantations or built infrastructure alters soil properties (e.g. organic matter content and erosion rates), reduces habitat availability and degrades ecosystem services that are essential for environmental and human health. [5-8] Recent assessments of planetary boundaries indicate that land-system change has exceeded the safe operating space, increasing risks to ecosystem stability and resilience. [4] The healthcare sector contributes to land-use impacts through both direct and indirect pathways. Direct land occupation arises from healthcare infrastructure, including hospitals, care facilities and associated services. However, the dominant share of land-use impacts linked to healthcare occurs upstream, embedded in the production of goods and services consumed by the sector. In particular, food provision for patients, staff and visitors, as well as biomass-based inputs such as cotton for medical textiles, paper products, furniture, and packaging, rely on cropland, pasture and forest land. [8, 9] The land-use environmental footprint captures the amount of land required – 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 occurs along international supply chains rather than at the point of care delivery. [10-12] Land use is closely interconnected with other environmental impact categories. Agricultural land use contributes to nutrient losses, water abstraction and chemical pollution, while deforestation and land conversion affect carbon stocks and climate regulation. [4-9] As a result, measures aimed at reducing environmental impacts in healthcare – such as replacing fossil-based materials with bio-based alternatives – may unintentionally increase land-use pressures if assessed in isolation. This underlines the importance of explicitly measuring land use as part of a multi-category environmental footprint.

	Circular economy strategies can help reduce land-use pressures by maintaining material value for longer, limiting demand for new biomass extraction and improving supply resilience (see also ENV-3). [13] In addition, dietary shifts towards more plant-based food provision have been shown to substantially reduce land requirements, as plant-based foods generally require far less land per unit of nutrition than animal-based products. [14, 15]
Calculation	Land use footprint was calculated by VITO (see methodological note) **Primary indicator (A):** • Numerator: Annual land use footprint of the healthcare sector, in km² • Denominator: Population of the corresponding year (calculated as mean of population at beginning and end of year) **Indicator B:** • Numerator: Annual land use footprint of the healthcare sector, in km² • Denominator: / **Indicator C:** • Numerator: Annual land use footprint of the healthcare sector, in km² • Denominator: Annual land use footprint over all sectors, in km²
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. [16]
Technical definitions	See methodological note Land use can be expressed either in km², representing the physical surface area, or in points (Pt), a normalized and weighted indicator used in European Environmental Footprint models. In this approach, land-use impacts on ecosystems (e.g. biodiversity and ecosystem quality) are normalized against a reference such as the annual environmental impact of an average EU citizen, making the result dimensionless, and then weighted based on expert judgment and policy relevance. [17, 18]
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 land use 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-2 Material environmental footprint of the healthcare sector ENV-13 Annual food waste in hospitals and residential care ENV-16 Annual water consumption in healthcare sector
Supervisor	Nicolas Bouckaert
Reviewer	Pieter Fonteyn (VITO)

1.3.2 Results

BELGIUM

Table 1 and Figure 1 present the annual land use footprint of the health system over the period 2012-2023, expressed using four complementary metrics: land occupation per capita (m² per capita), total land occupation (km²), land-use impact weighted by soil quality (Pt per capita), and total land-use impact (billion Pt). Results are further disaggregated by current spending versus investments.

The total land-use footprint declined from 0.54 m² per capita in 2012 (6 007 km²) to 0.48 m² per capita in 2022 (5 587 km²). Over the period 2012-2018, land use showed considerable variability, with higher values in 2015 and 2018 and lower values in the intervening years, ranging between 0.47 and 0.56 m² per capita. From 2018 onwards, land use gradually declined, reaching its lowest level at the end of the period. Overall, the land-use footprint in 2022 is lower than in 2012, indicating a modest reduction in land occupation per capita. No COVID-related peak is observed, reflecting the specific scope of this indicator.

When accounting for land-use quality, expressed in points (Pt) reflecting impacts on soil quality due to land occupation and transformation, similar patterns emerge. The land-use impact ranged from 18.42 thousand Pt per capita (204 billion Pt) in 2012 to 16.74 thousand Pt per capita (195 billion Pt) in 2022, with higher levels observed in 2015 and 2018.

Across all metrics, current spending accounts for the majority of the land-use footprint, reflecting the structurally recurring demand for food provision and other biomass-based products and services embedded in healthcare delivery. Investments represent a smaller share and show a marked decline over time. Between 2012 and 2022, the absolute reduction in the land-use footprint of investments (-319 km²) exceeds that of current spending (-101 km²), while per capita land use associated with investments decreased by around 40%.

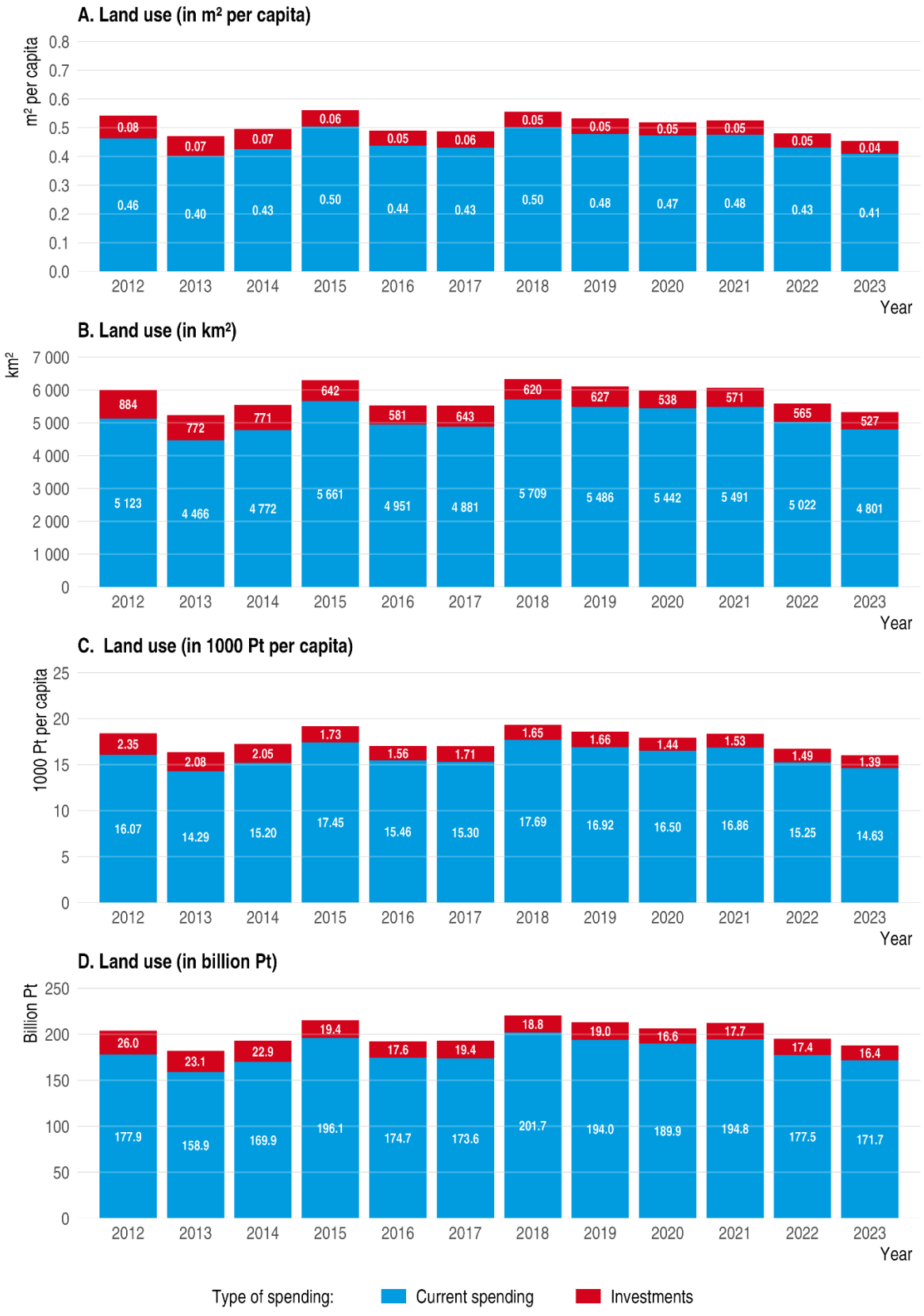
Table 1 – Annual land use footprint of the health system (in m² per capita, km², 1000 Pt per capita, billion Pt)

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	(2023*)
Results by surface												
in m² per capita	0.54	0.47	0.50	0.56	0.49	0.49	0.55	0.53	0.52	0.52	0.48	0.45
in km²	6 007	5 238	5 543	6 303	5 532	5 524	6 329	6 113	5 980	6 062	5 587	5 328
Results by surface quality												
in 1000 Pt per capita	18.42	16.36	17.25	19.17	17.02	17.01	19.33	18.58	17.94	18.39	16.74	16.03
In billion Pt	203.8	182.1	192.8	215.5	192.3	193.0	220.5	213.0	206.5	212.5	194.9	188.0

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 land use footprint of the health system by investment versus current spending (in m² per capita, km², 1000 Pt per capita, billion Pt)



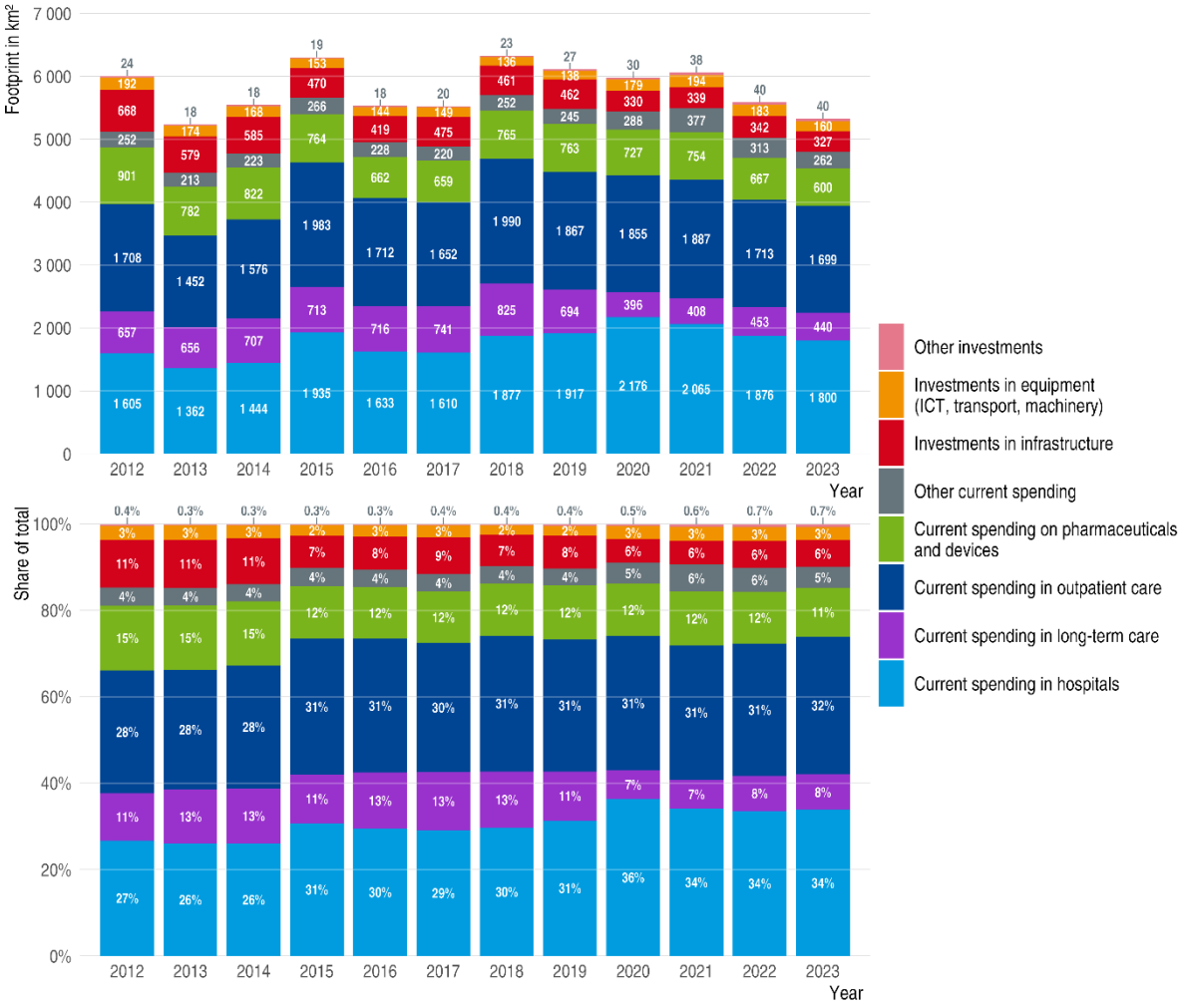
Source: VITO, Eurostat

ANALYSIS BY SPENDING CATEGORY

Figure 2 presents the annual land use footprint of the health system over the period 2012-2023, disaggregated by current spending categories and investment types, and shown both in absolute terms (km²) and as shares of the total footprint. The figure illustrates where land use demand is generated within the health system. As also shown in Figure 1, current spending dominates land use in all years, accounting for approximately 85-90% of the total footprint. Within current spending, hospital care and outpatient care are the largest contributors and together consistently represent around 55-65% of total land use, with their share increasing over time. Long-term care and pharmaceuticals and medical devices contribute smaller and declining shares, generally in the range of 7-13% and 11-15%, respectively, while other current spending remains marginal. Investments account for a smaller share of land use, typically 10-15%, with infrastructure responsible for roughly two thirds of the investment-related footprint and equipment (including ICT, transport and machinery) for about one third.

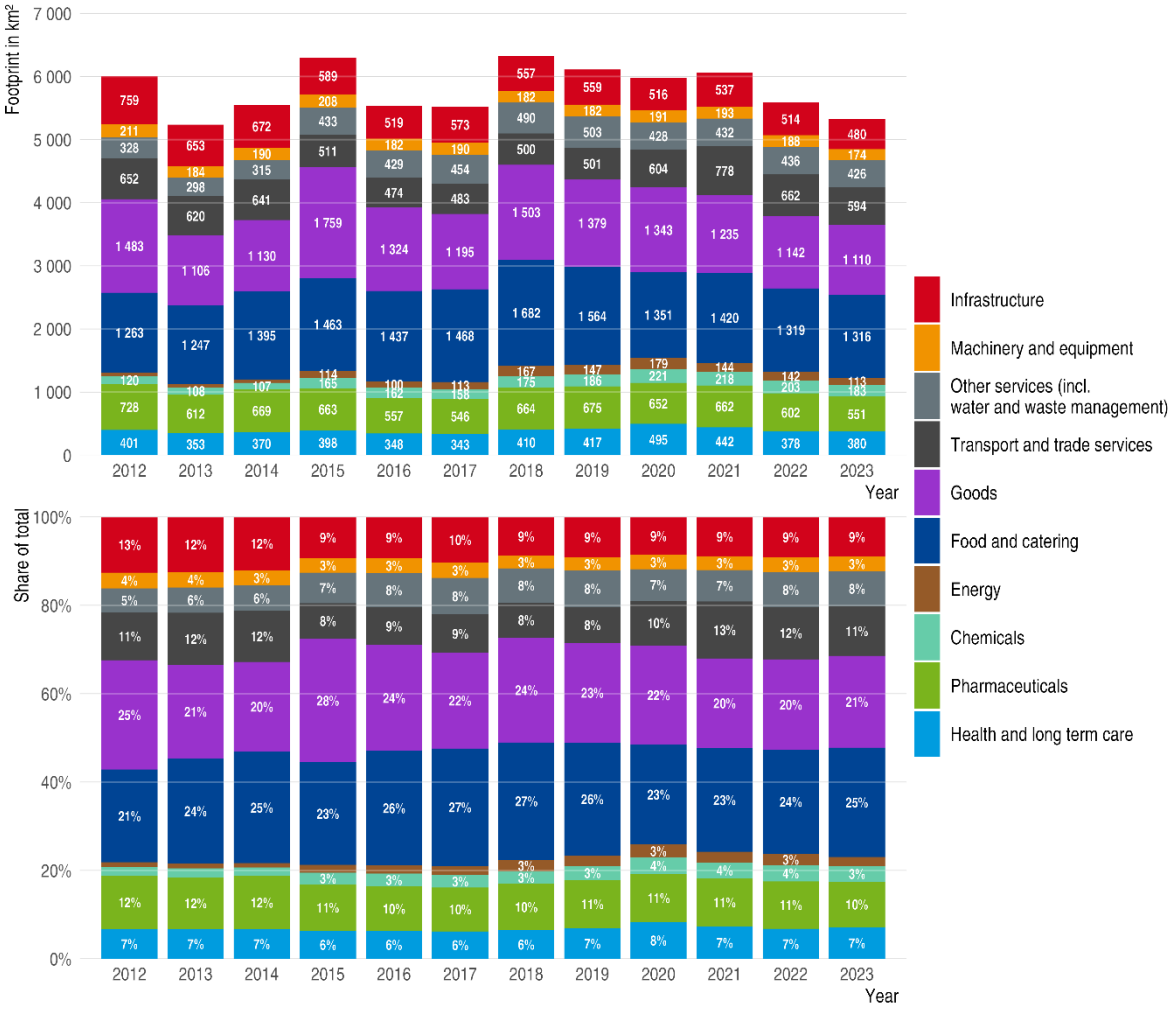
Higher total land use in 2015 and 2018 coincides with increased environmental impact in hospital and outpatient care. Although no COVID-related peak is observed in absolute land use, a shift in relative shares towards hospital and outpatient care is apparent, reflecting changes in budget allocation during the pandemic.

Figure 2 – Annual land use footprint of the health system by spending category (in km²)



Source: VITO

Figure 3 – Annual land use footprint of the health system by trigger product or service (in km²)



Source: VITO
Note: No numeric labels are shown for categories with values below 100 km² or 2.5%.

ANALYSIS BY TRIGGER PRODUCT OR SERVICE

Figure 3 presents the annual land use footprint of the health system by trigger product or service over the period 2012-2023, expressed in km² and relative shares. Trigger products or services refer to the goods or services directly purchased by the healthcare sector that initiate upstream land use along supply chains in the input-output framework. This perspective complements the breakdown by spending category by identifying which types of products and services directly initiate land use along global supply chains.

Land use is dominated by goods and food and catering, each accounting for approximately 20-25% of the total footprint. Food and catering is a major contributor due to the land-intensive nature of agricultural production embedded in healthcare-related food provision. Other relevant contributors include pharmaceuticals, transport and trade services, and infrastructure-related activities, each accounting for around 10% of the total footprint. By contrast, energy and chemicals represent only minor shares.

Overall, the figure shows that healthcare-related land use is driven largely by enabling goods and services, such as infrastructure, transport, food and other supporting goods and services that underpin healthcare delivery, rather than by direct healthcare products, such as pharmaceuticals and medical products.

STRUCTURE AND ORIGINS OF THE HEALTHCARE LAND USE FOOTPRINT (2022)

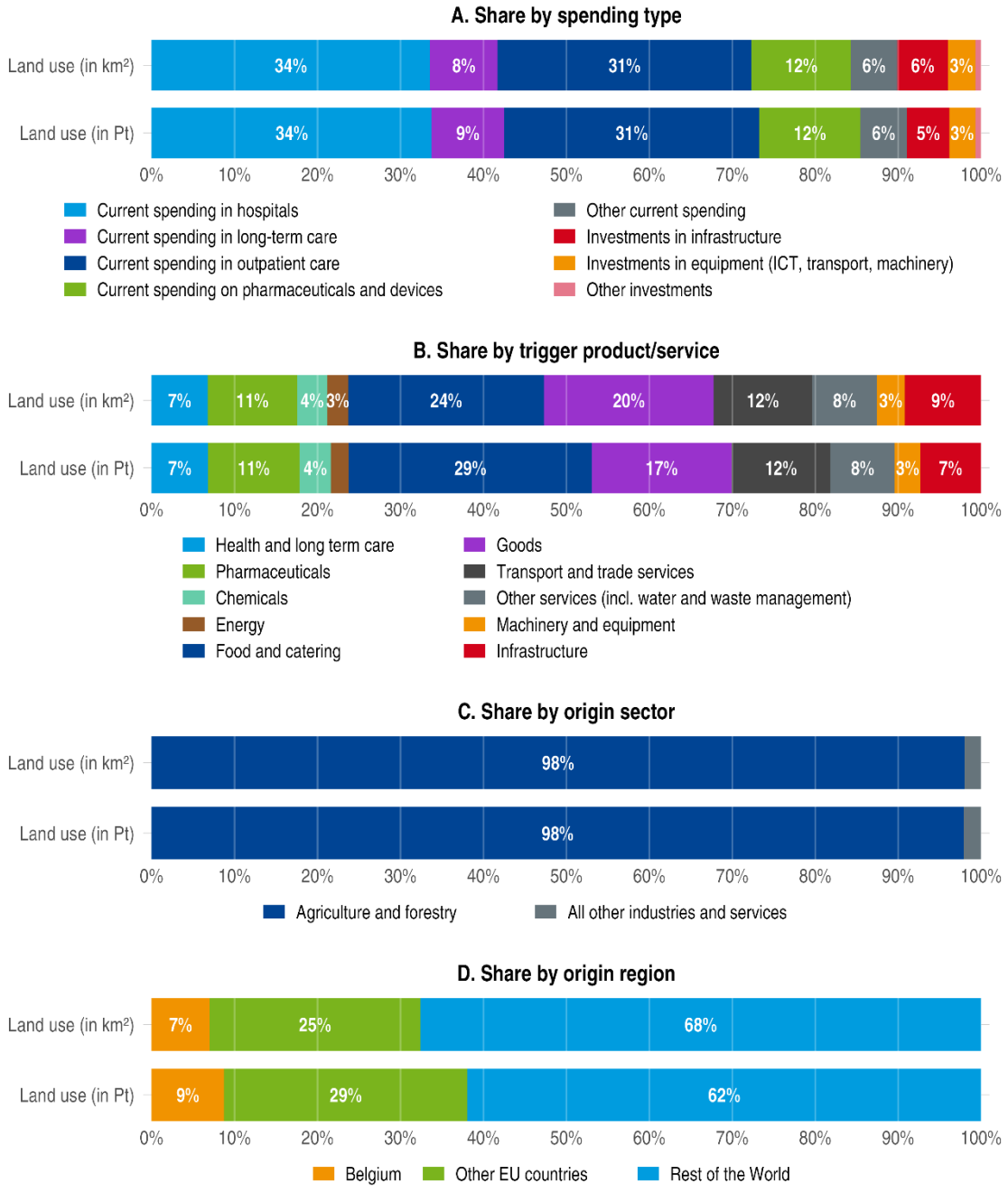
Figure 4 presents the relative composition of the land use footprint of the health system in 2022, expressed both in surface area (km²) and surface-quality-weighted impacts (Pt), and disaggregated by spending category (A), trigger product or service (B), origin sector (C) and origin region (D).

Panels A and B summarise patterns described in more detail above. Panel A shows that current spending, in particular hospital and outpatient care, accounts for the majority of the footprint, while investments represent a smaller share. Panel B indicates that, in terms of trigger products and services, land use is mainly driven by food and catering and goods, reflecting the land-intensive nature of agricultural production embedded in healthcare supply chains. Pharmaceuticals and transport and trade services also account for shares above 10%. Some notable differences emerge between results expressed in km² and in Pt, with quality-adjusted results assigning relatively more weight to food-related land use and less to goods and infrastructure.

Panel C shows that land use associated with healthcare consumption is almost entirely attributable to agriculture and forestry, which account for approximately 98% of total land occupation in both km² and Pt. This underscores that healthcare-related land use is overwhelmingly driven by biomass production.

Panel D highlights the geographical origin of land use. Land use is primarily driven by agricultural land occupation outside national borders. In terms of surface area, around two thirds (68%) of land use occurs in the rest of the world, with 25% in other EU countries and 7% in Belgium. When weighted by surface quality (Pt), the share of land use occurring in Belgium and the EU increases slightly, while the share attributed to the rest of the world decreases to around 62%. This indicates that land use within Europe is, on average, associated with higher impacts on soil quality per unit of area.

Figure 4 – Land use footprint of the health system in 2022, relative shares by spending category, trigger product or service, origin sector, and origin region (in surface area and weighted by surface quality)



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

SHARE OF HEALTH SECTOR IN BELGIAN LAND USE ENVIRONMENTAL FOOTPRINT

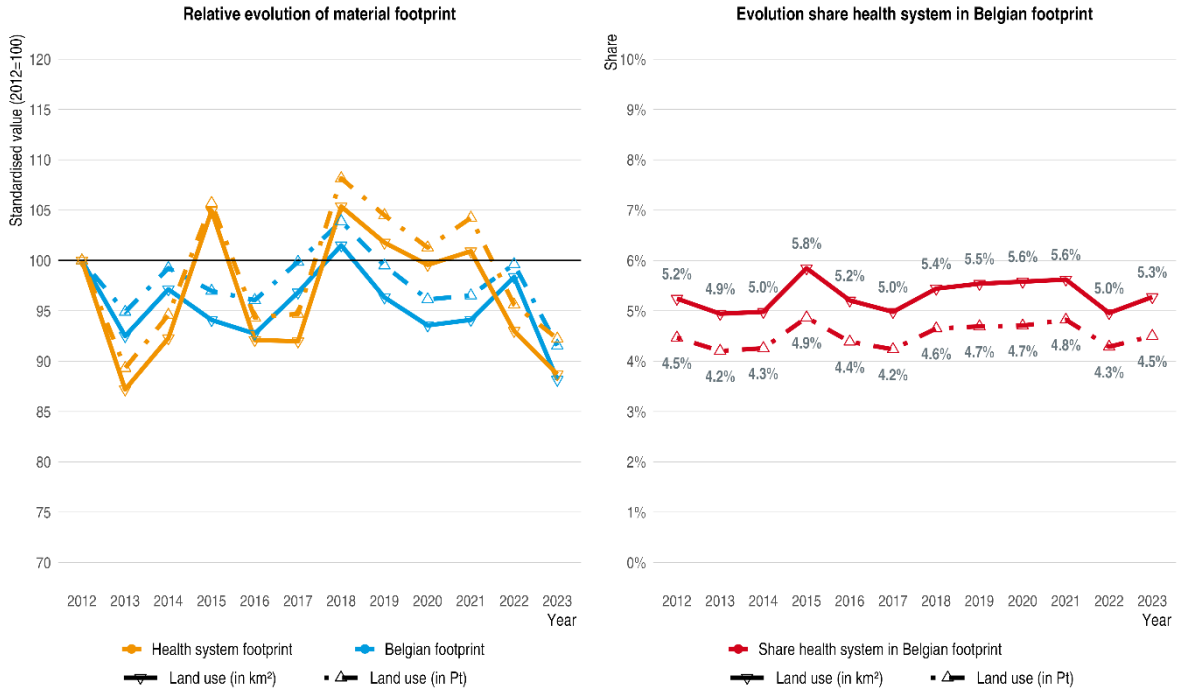
Figure 5 compares the relative evolution of the land use footprint of the health system with that of the overall Belgian land use footprint over the period 2012-2023 (left panel), with 2012 values standardised to 100, and shows the corresponding share of the health system in the Belgian land use footprint (right panel), expressed both in km² and surface-quality-weighted impacts (Pt).

The left panel shows that the land use footprint of the health system broadly follows the same trajectory as the overall Belgian footprint. After a period of fluctuation between 2012 and 2018, land use declined

gradually for both. Two notable divergences can be observed: a relative peak in healthcare-related land use in 2015, and a peak in overall Belgian land use in 2022, linked to the post-COVID rebound in consumption. No clear COVID-related surge is observed for healthcare land use, reflecting the limited impact of the pandemic on food provision and other biomass-intensive activities within the health system. Trends based on surface area and quality-weighted impacts are similar, although quality-weighted values are consistently higher, suggesting that reductions in land use over time occurred relatively more on land with lower soil-quality impacts.

The right panel shows that the share of the health system in the Belgian land use footprint remains relatively stable over time. Healthcare accounts for approximately 4.9-5.8% of total land use when expressed in km², while its share is substantially lower, around 4.2-4.9%, when weighted by surface quality. This suggest that healthcare-related land use is, on average, associated with somewhat lower soil-quality impacts than land use in the broader economy.

Figure 5 – Relative evolution of the land use footprint of the health system and Belgium since 2012 and evolution of the share of the health system in the Belgian land use footprint



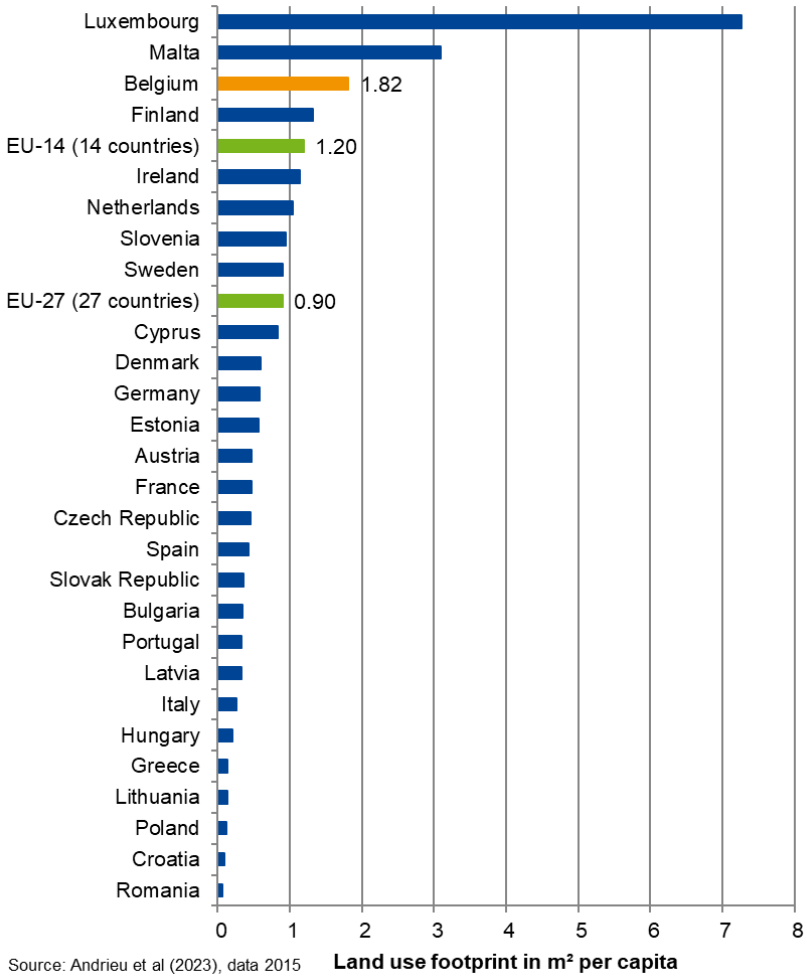
Source: VITO

INTERNATIONAL COMPARISON

Figure 6 presents an international comparison of the land-use footprint of the healthcare sector in 2015, expressed in m² 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. [19] The Belgian estimates are approximately 3 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 across EU countries. Belgium records a land-use footprint of 1.82 m² per capita, which is above the EU-27 average (0.90 m²) and the EU-14 average (1.20 m²), placing Belgium among the higher-impact countries. Only a limited number of countries, notably Luxembourg and Malta, show higher per-capita values, while most EU Member States display considerably lower land-use footprints for the healthcare sector.

Figure 6 – Land use footprint of the healthcare sector in 2015, international comparison (in m² per capita)



Source: Andrieu et al (2023), data 2015

KEY POINTS

- **The land use footprint of the health system declined modestly over time.** Between 2012 and 2022, land use decreased from 0.54 to 0.48 m² per capita (from 6 007 to 5 587 km²). Fluctuations occurred between 2012 and 2018, with peaks in 2015 and 2018, followed by a gradual decline. No COVID-related peak is observed, reflecting the structurally biomass-driven nature of this indicator.
- **Healthcare represents a stable share of Belgium's land use footprint.** The health system accounts for around 4.9-5.8% of total Belgian land use in surface area terms and drops to 4.2-4.9% when weighted by soil-quality impacts. This indicates that healthcare-related land use is, on average, associated with somewhat lower soil-quality impacts than land use in the broader economy.
- **Current spending dominates land use, while investment-related land use declined strongly.** Current spending consistently represents 85-90% of the land use footprint, driven by recurring demand for food and other biomass-based goods. Hospital and outpatient care together account for 55-65% of total healthcare-related land use and increased over time. Investments represent 10-15% but declined sharply, with per capita land use falling by around 40% between 2012 and 2022.
- **Land use is mainly driven by enabling goods and services that support healthcare delivery, rather than by direct healthcare products.** Food and catering and goods each account for 20-

25% of land use, while pharmaceuticals, transport and trade services, and infrastructure-related activities each contribute around 10%. Quality-weighted results assign relatively more weight to food-related land use and less to goods and infrastructure.

- **Land use is primarily driven by agricultural land occupation abroad.** Around 98% of land use originates in agriculture and forestry, highlighting the dominance of biomass production. Approximately two thirds of land use occurs outside the EU, while only 7% takes place in Belgium, underscoring reliance on global supply chains.
- **Belgium has a relatively high healthcare land-use footprint in international comparison.** Using the latest available internationally comparable data (2015), Belgium records a land-use footprint of 1.82 m² per capita, well above the EU-averages (EU-27: 0.90 m², EU-14: 1.20 m²), placing it among the higher-impact countries. These figures are based on the EXIOBASE EE-MRIO model 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)		

Code	Label	Trigger categories	Origin sector categories
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
Supervisor	Nicolas Bouckaert

Co-authors / Reviewers	Maarten Christis (VITO), Pieter Fonteyn (VITO)

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