1 OVERALL ENVIRONMENTAL FOOTPRINT OF THE HEALTH SYSTEM

1.1 GHG environmental footprint of the healthcare sector (direct and indirect emissions - Scope 1, 2 and 3) (ENV-1)

1.1.1 Documentation sheet

Description	**Primary indicator**: • Direct and indirect GHG emissions in the healthcare sector (in kg CO_2 eq per capita) (Scope 1, 2, 3) **Secondary indicators:** • Direct and indirect GHG emissions in the healthcare sector (% of total Belgian GHG emissions) (Scope 1, 2, 3) • Direct and indirect GHG emissions in the healthcare sector (in kt CO_2 eq) (Scope 1, 2, 3) • GHG emissions (in kt CO2 eq) related to building and energy • GHG emissions (in kt CO2 eq) related to transport and mobility • GHG emissions (in kt CO2 eq) related to medical products • GHG emissions (in kt CO2 eq) related to sustainable food • GHG emissions (in kt CO2 eq) related to waste management and water use
Rationale	Greenhouse gases (GHG) like carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) trap heat, leading to global warming and climate change. Belgium formally committed to deliver a baseline assessment of greenhouse gas emissions of the health system, with the final objective of developing a climate resilient and low carbon, sustainable health system by 2050. [1];
Calculation	**Primary indicator (A):** • Numerator: GHG emissions footprint of the health system in kt CO2 eq (2022) • Denominator: Population of the corresponding year (calculated as mean of population at beginning and end of year) **Indicator B:** • Numerator: GHG emissions footprint of the health system in kt CO2 eq (2022 in NEHAP, 2018 in OECD) • Denominator: Total GHG emissions in Belgium (2021 in NEHAP, 2018 in OECD) **Indicator C:** • Numerator: GHG emissions footprint of the health system in kt CO2 eq (2022) • Denominator: - **Indicators D-G:** • Numerator: GHG emissions for “XXX” in kt CO2 eq (2022) (XXX = construction and maintenance services / fossil fuels, etc.) • Denominator: GHG emissions footprint of the health system in kt CO2 eq (2022)
Data source	Three different models were used: NEHAP 2025[2], VITO 2025 (see methodological note on VITO model), and OECD 2025[3]
Technical definitiefs	All direct (scope 1) and indirect (i.e. scope 2 and 3) emissions were considered based on greenhouse gas (GHG) emission inventory of the Belgian healthcare sector using a footprint (consumption-based) methodology. Scope 1 emissions are direct emissions associated with on-site fuel combustion (e.g. in boilers, heating systems, combined heat and power, backup power generation etc.) in

	healthcare facilities, emissions from the operation of fleet vehicles and other on-site emissions (from refrigerants, anaesthetics or on-site waste treatment). Scope 2 emissions are indirect emissions associated with the generation of purchased electricity, heat or steam. Scope 3 emissions are indirect emissions from upstream (e.g. material extraction, production of pharmaceuticals) and downstream (e.g. waste and sanitation) organizational activities. Scope 3 emissions include those related to pharmaceuticals, business services, medical equipment/instruments, food/catering, manufactured fuels, chemicals, and gases, other manufactured products, construction and maintenance services, other procurement, information and communication technologies and services, fossil fuels (coal, oil, etc.), transport, waste, water, and sanitation, electricity and steam. [2] The NEHAP model used the Health Care Without Harm's "Net Zero Roadmap" methodology. Emissions baseline was derived using a "hybrid" approach, combining both top-down expenditure where detailed and consistent activity-level data is lacking and more granular, precise bottom-up data where available. For top-down expenditure, an Environmentally-Extended Input-Output (EEIO) analysis was done. Emissions factors tied to product-based expenditure for Belgium were derived using the EXIOBASE 3 (version 3.8.2) environmentally extended multi-regional input-output (EE MRIO) tables. In EXIOBASE 3, the detailed supply–use structure is benchmarked to 2011; subsequent years are updated using macroeconomic and trade-based now-casting rather than newly compiled national supply–use tables. This methodological choice may explain some of the observed differences relative to other Multi-Regional (MR)-EEIO models. For bottom-up data, the following sources were used: Electricity and natural gas consumption across health facilities, and Metered Dose Inhalers (MDI) usage. Adjustments were made to top-down derived emissions figures reflecting energy consumption and pharmaceutical procurement to help improve the precision of the associated emissions derivation methods and incorporate scope 1 emissions that are not captured in emissions factors (EFs) from EXIOBASE. Health care activities included (based on classifications from the system of health accounts produced by OECD/Eurostat/WHO) were hospitals, residential long-term care facilities, providers of ambulatory health care, providers of ancillary services, retailers and other providers of medical goods, providers of preventative care, providers of health care system administration and financing (for more details, see table 1 in NEHAP 2025[2]). The OECD model used a "top-down" approach combining OECD's Inter-Country Input Output (ICIO) table, its environmental extension, and the JHAQ data collection on health expenditure (See Doucet at al. 2025 for more details) [3] The VITO model used a "top-down" Environmentally Extended Multi-Regional Input-Output (EE-MRIO) approach. Environmental extensions tables were based on EXIOBASE v3.8.2 and supplemented by VITO with Eurostat Air Emission Accounts data (2023 update). Monetary tables used were FIGARO (25 edition) tables published by Eurostat, in which the region-level granularity was adjusted to cover the 46 regions of earlier FIGARO releases (see methodological note on VITO model for more details). As FIGARO is closely aligned with OECD's ICIO, OECD and VITO results are more similar than NEHAP. Moreover, NEHAP uses some bottom-up data, which is not the case in other models. It should also be noted that in the VITO model, 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.
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. The International comparison is therefore based on results from the OECD model. [3] Among the model components, the GHG emission vector for all industries and all countries is likely less robust and more assumption driven than other components. There seems to be greater cross-country variation in how emissions are allocated to industries. However, discussions to improve comparability are ongoing.

Limitations	Results differ by model. Differences in the sources used and assumptions done impacted results. Details on the limitations of each model can be found in their respective reports (NEHAP 2025[2], Doucet 2025[3] and methodological note on VITO model.
Dimension	Environmental sustainability
Related indicators	ENV-4 Direct GHG emissions in human health activities ENV-2 Material environmental footprint of the healthcare sector ENV-3 Land use environmental footprint of the healthcare sector
Supervisor	Sophie Gerkens
Reviewers	Pieter Fonteyn (VITO), Ben Ashby (ARUP), Michael Mueller (OECD)

1.1.2 Results

BELGIUM

Based on the NEHAP report, direct and indirect GHG emissions in the healthcare system reached 9 901 kt CO_2 eq in 2022, representing 5% of total Belgian emissions and 850.5 kg CO_2 eq per capita. Scope 3 indirect emissions represented the most important part (86.4%) while direct emissions scope 1 represented 10.9% of total GHG emissions of the healthcare sector. A similar distribution is observed in the OECD model (based on 2018 data), where Scope 3 emissions represented 81.8% and Scope 1 emissions 12.1% of total emissions.

The model used by VITO provides longitudinal data on the evolution of GHG emissions. Based on this model, emissions were slightly lower than in the NEHAP report (7 321 kt CO_2 eq in 2022) and the evolution seems quite stable (see Figure 1). When accounting for the increase in population, we observe a small decline in the GHG emissions per capita, with the lower value observed in 2022 (2023 incomplete). The share of the health system in the Belgian GHG footprint remains relatively stable over time, fluctuating within a range of 4.9% and 5.5% (excluding 2020 and 2021). A temporary increase is observed during 2020-2021 (5.8%), reflecting the comparatively stronger rise in healthcare-related GHG emissions during the pandemic (see Table 1).

Finally, in the OECD model, emissions were slightly higher than in the VITO model (see Table 2).

Table 1 – Annual direct and indirect GHG emissions in the healthcare sector, 2012-2023

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	*(2023*)*
In kg CO_2 eq per capita	694.9	684.6	663.8	710.8	648.3	634.6	693.0	665.9	666.2	694.0	628.9	607.7
In kt CO_2 eq	7 691	7 617	7 422	7 988	7 323	7 202	7 903	7 633	7 666	8 018	7 321	7 129
As a share of total Belgian GHG emissions (%)	5.0%	4.9%	4.9%	5.5%	5.0%	4.9%	5.1%	5.2%	5.8%	5.8%	5.1%	5.5%

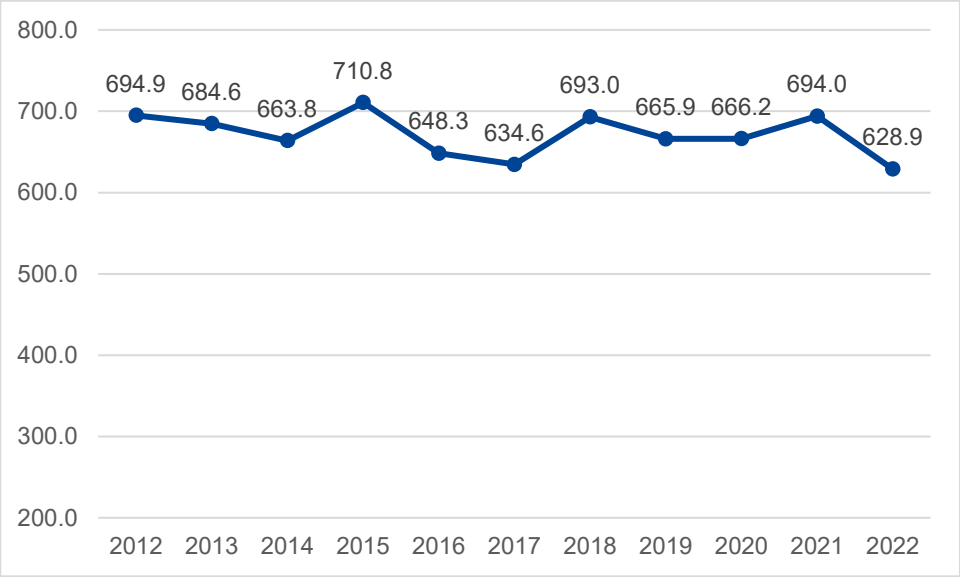
**2023 results are preliminary and likely overestimated, as they are based on 2022 environmental intensities combined with 2023 monetary data without inflation adjustment. Source: VITO 2025*

Table 2 – Direct and indirect GHG emissions in the healthcare sector, by source (NEHAP, VITO, OECD)

Unit (year)	NEHAP	VITO	OECD
in kt CO_2 eq (2022)	9 901	7 321	
in kg CO_2 eq per capita (2022)	851	629	
As a share of total Belgian GHG emissions (%) (2022)	5%	5.1%	
in kt CO_2 eq (2018)		7 903	8 336
in kg CO_2 eq per capita (2018)		693	731
As a share of total Belgian GHG emissions (%) (2018)		5.1%	5.5%

Sources: NEHAP, VITO, OECD

Figure 1 – Annual direct and indirect GHG emissions in the healthcare sector, in kg CO_2 eq per capita, 2012-2022



Source: VITO 2025

ANALYSIS BY TRIGGER PRODUCT OR SERVICE

Based on the NEHAP report, Medical products (pharmaceuticals, medical equipment and instruments – scope 3) accounted for the largest share of emissions in the health system, i.e. 44.3%[1] (see Table 3 and Figure 2). Within this category, pharmaceuticals alone represent 30.8%, making them the single most important trigger of healthcare-related GHG emissions. Emissions from Metered Dose Inhalers (MDIs) represented 0.4% of the GHG footprint (44 kt CO_2 eq).

Building and energy use is responsible for 15.0% of emissions. These emissions arise from a combination of direct on-site fuel combustion (scope 1), purchased electricity and heat (scope 2), and upstream energy supply (scope 3), reflecting the energy-intensive nature of healthcare facilities. The category “Other” represents a substantial 28.6% of total emissions, driven mainly by business services (16.4%) and manufactured fuels, chemicals, and gases (5.4%). Food and catering contribute 7.8% of

[1] The high contribution from pharmaceutical and chemical products may in part be related to the use of EXIOBASE as the EE-MRIO, which assigns relatively high emission intensities to these industries compared with ICIO or FIGARO.

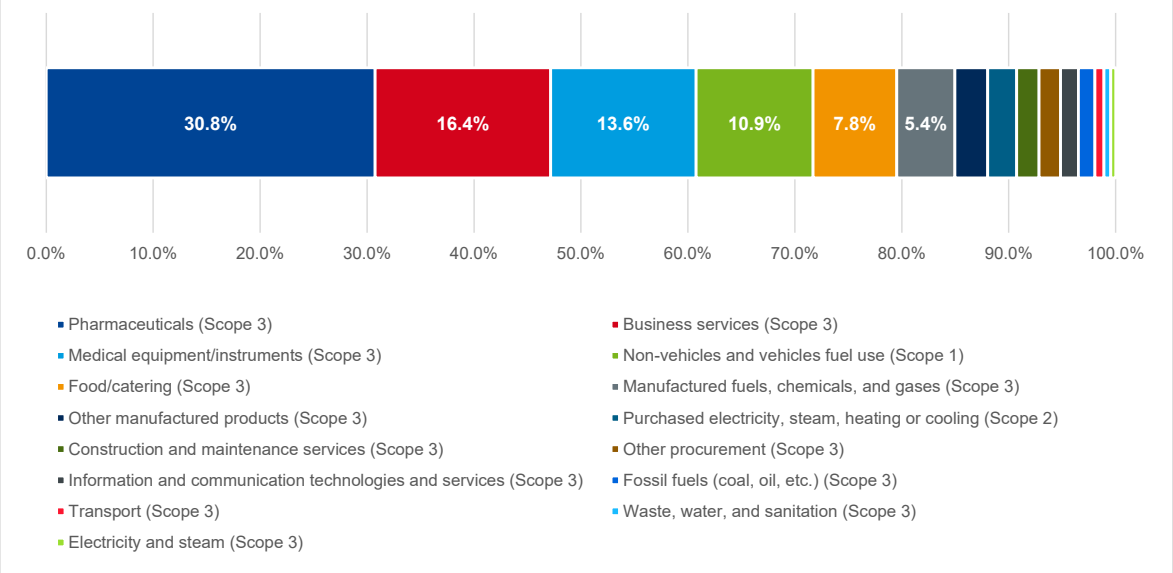
emissions, while transport and mobility account for a smaller share (3.7%), largely driven by vehicle fuel use.

Table 3 – Details on GHG emissions by trigger product or service

Topic	kt CO_2 eq	%
Building and energy use	***1480***	***14.95%***
Non-vehicles fuel use (scope 1)	806	8.14%
Purchased electricity, steam, heating or cooling (scope 2)	269	2.72%
Fossil fuels (coal, oil, etc.) (scope 3)	152	1.54%
Electricity and steam (scope 3)	208	2.10%
Construction and maintenance services (scope 3)	45	0.45%
Transport and mobility	***361***	***3.65%***
Vehicles fuel use (scope 1)	277	2.80%
Transport (scope 3)	84	0.85%
Medical products	***4391***	***44.35%***
Pharmaceuticals (scope 3)	3045	30.75%
Medical equipment/instruments (scope 3)	1346	13.59%
Sustainable food	***775***	***7.83%***
Food and catering (scope 3)	775	7.83%
Waste and water use	***63***	***0.64%***
Waste, water, and sanitation (scope 3)	63	0.64%
Other	***2831***	***28.59%***
Business services (scope 3)	1625	16.41%
Manufactured fuels, chemicals, and gases (scope 3)	539	5.44%
Information and communication technologies and services (scope 3)	166	1.68%
Other procurement (scope 3)	198	2.00%
Other manufactured products (scope 3)	303	3.06%

Source: NEHAP 2025

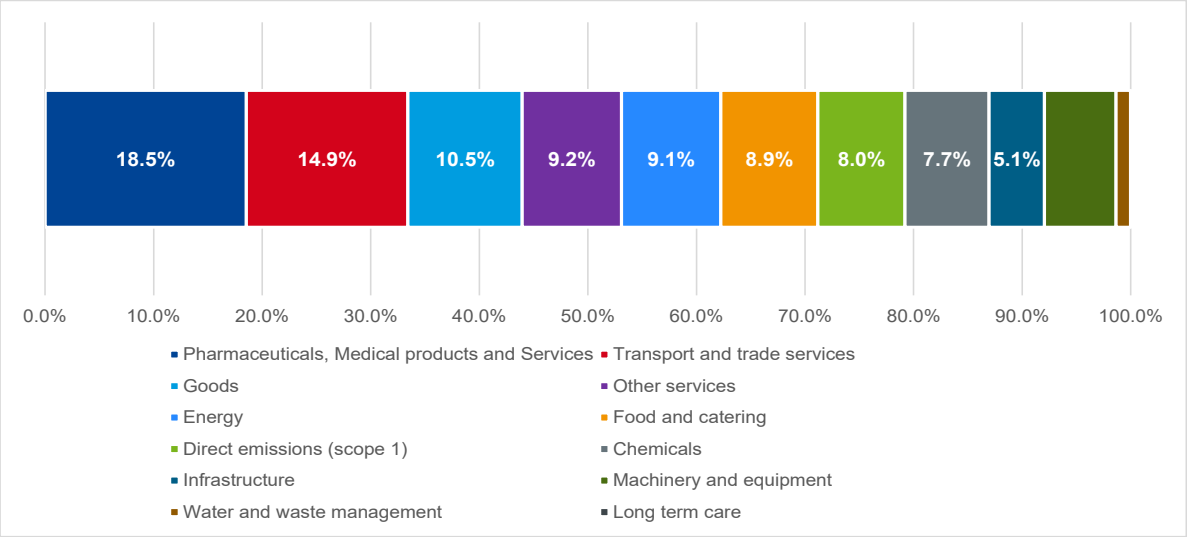
Figure 2 – Details on GHG emissions by trigger product or service (NEHAP)



Sources: NEHAP 2025

Based on the VITO model, the repartition was slightly different but pharmaceuticals and medical products remain among the main drivers, but with a substantially lower share (see Figure 3). One reason for this is that the FIGARO model used by VITO has a dedicated pharmaceutical sector in the IO analysis, while EXIOBASE groups pharmaceuticals within a broader "chemicals not elsewhere classified" category, which may result in higher and less precise estimates.

Figure 3 – Details on GHG emissions by trigger product or service (VITO)



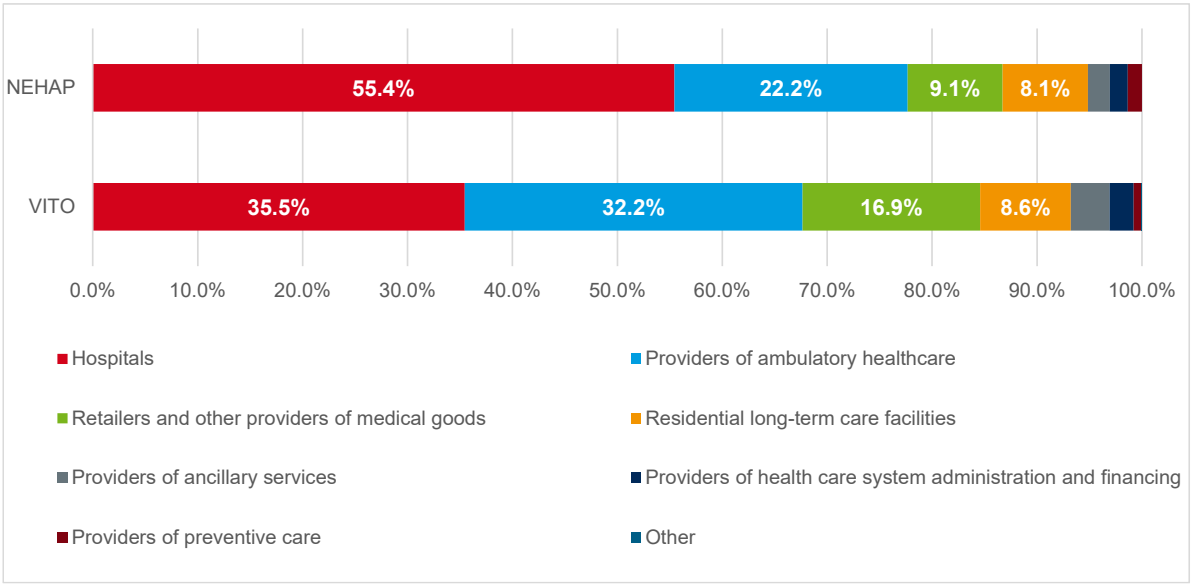
Sources: VITO 2025

ANALYSIS BY HEALTH CARE PROVIDERS

Based on the NEHAP model and spending categories, hospitals are the largest contributors to GHG emissions (55.4%), followed by providers of ambulatory healthcare (22.2%), retailers and other suppliers of medical goods (9.1%), and residential long-term care facilities (8.1%). Other providers account for less than 2.2%. The link between the high share of pharmaceutical products as triggers products and the high share of hospitals as providers can be partly explained by the fact that, in Belgium, pharmaceutical expenditures are largely attributed to hospitals (53.2% in 2022). [4]

The same hierarchical pattern is observed in the VITO model, with hospitals remaining the main contributors but at a lower share (see Figure 4). This difference can partially be explained by the exclusion of direct emissions and emissions related to investments (not allocated to healthcare providers in the VITO model). It should also be noted that the OECD model produces results comparable to those obtained by VITO (see the appendix of the OECD report). [3] These results are not included in the figure, as the OECD model is based on a different reference year (2018).

Figure 4 – Details on GHG emissions by healthcare provider (NEHAP and VITO models)

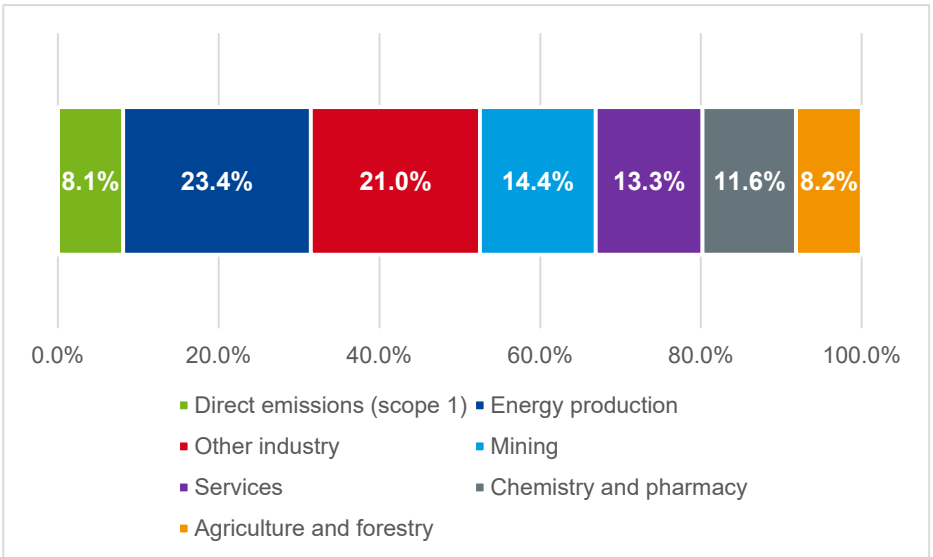


Sources: NEHAP 2025 and VITO 2025 (For VITO, direct emissions and emissions related to investments were not taken into account)

ANALYSIS BY SECTORAL ORIGIN

Based on the VITO model, Figure 5 illustrates the sectoral sources of GHG emissions associated with healthcare consumption in 2022. Beyond direct emissions from the healthcare sectors (8.1%), energy production stands out as the main contributor of GHG emissions (23.4%), followed by other industrial sectors (21.0%), mining (14.4%), services (13.3%), chemistry and pharmacy (11.6%), and agriculture and forestry (8.2%). Contrary to the material use and land-use footprints, which are dominated by 1 or 2 sectors, multiple sectors contribute a substantial share to the GHG footprint. A similar analysis can also by found in the appendix of the OECD report, but based on 2018 data).

Figure 5 – Details on GHG emissions by sectoral origin (VITO)



Sources: VITO 2025

REGIONAL COMPARISON

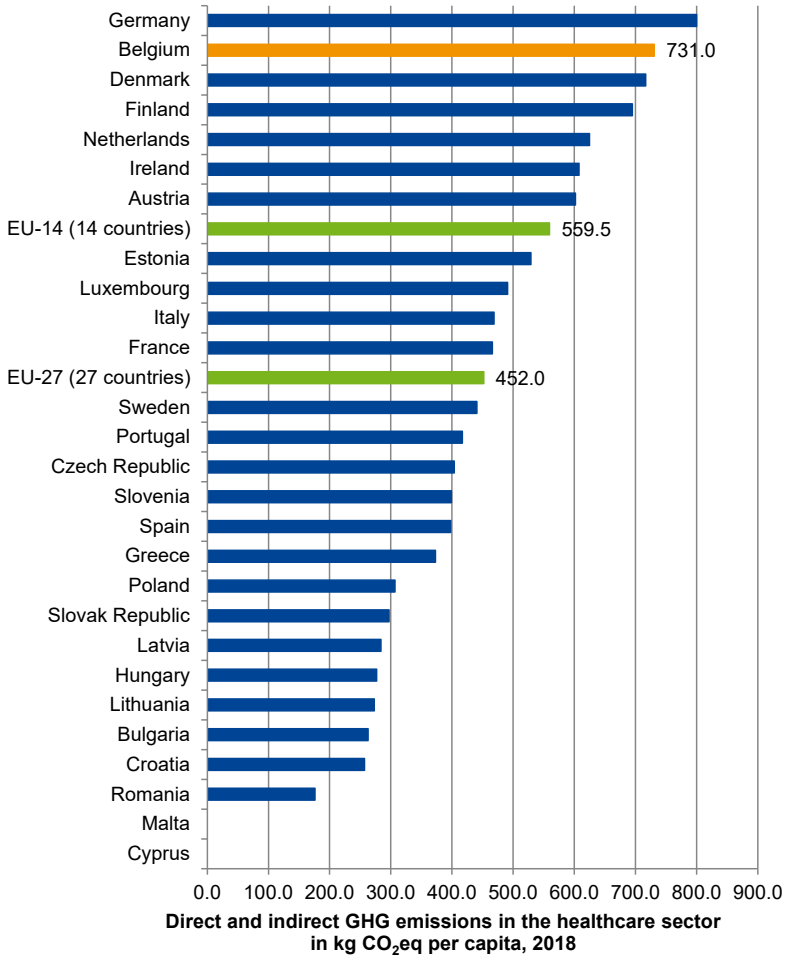
Even if the NEHAP report published data per region, these data were not reliable as the national level results were disaggregate by region based on the population[2].

Due to this methodological choice, no difference in GHG emissions per capita between regions could be highlighted. Regional data are therefore not reported to avoid inappropriate comparisons.

INTERNATIONAL COMPARISON

As methodological assumptions, data sources and choices made in each model can have a substantial impact on results, it is important to use the same model for country comparisons. Based on the OECD model, GHG emissions per capita in Belgium were above the EU-averages and Belgium was the second highest country in 2018, just after Germany (see Figure 6). GHG emissions in the healthcare sector in Belgium, expressed as a share of total GHG emissions for all sectors are also higher in Belgium than the EU-averages and Belgium was the fourth highest country in 2018 (see Figure 7).

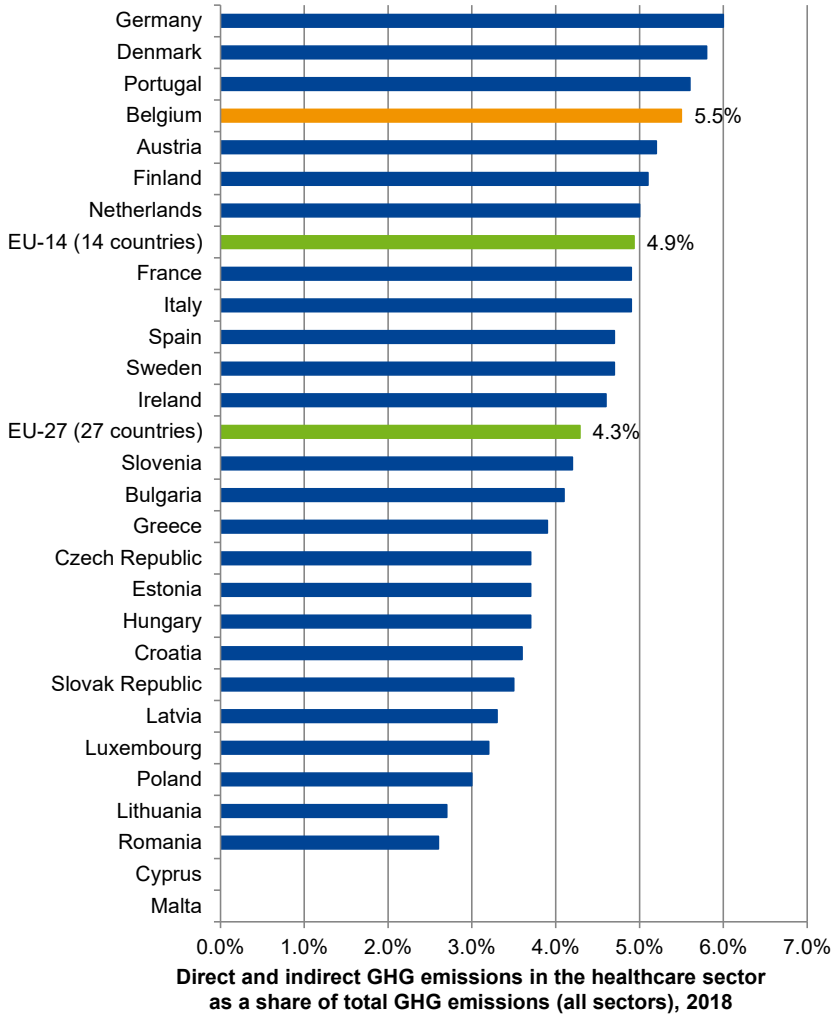
Figure 6 – Direct and indirect GHG emissions in the healthcare sector, in kg CO_2 per capita, international comparison, 2018



Source: OECD 2025

[2] The only regional differences captured concerned bottom-up electricity and natural gas consumption data

Figure 7 – Direct and indirect GHG emissions in the healthcare sector, as a share of total GHG emissions (all sectors), international comparison, 2018



Source: OECD 2025

KEY POINTS

- Assessing direct and indirect GHG emissions in the healthcare sector is complex, and results vary depending on the model and assumptions applied. While these estimates should be interpreted with caution, understanding the magnitude and trends of these emissions remains essential to achieve a climate-resilient, low-carbon, and sustainable health system by 2050.
- To estimate these emissions, this report used data from three different models: NEHAP[2], VITO, and OECD[3] (see the technical sheet for details).
- Estimated direct and indirect GHG emissions in the healthcare sector in 2022 ranged between 7 321 and 9 901 kt CO_2 eq, depending on the model. On a per capita basis, this corresponds to 629–851 kg CO_2 eq.
- When accounting for the increase in population, a small decline in the GHG emissions per capita is observed, with the lowest value observed in 2022 (629 kg CO_2 eq per capita) and the highest value in 2015 (711 kg CO2 per capita). The share of the health system in the Belgian GHG footprint remains relatively stable over time, fluctuating within a range of 4.9% and 5.5% but a temporary

increase to 5.8% was observed during the COVID-19 pandemic (based on the VITO model, no evolution available for other models).

- Scope 3 emissions dominated, accounting for 86.4% of total healthcare-related GHG emissions in 2022, while Scope 1 direct emissions represented 10.9%. Medical products (pharmaceuticals, medical equipment, and instruments – scope 3) were the largest contributors at 44.3%. Among healthcare providers, hospitals accounted for 55.4% of emissions (based on the NEHAP model). The link between the high impact of pharmaceutical products and the high impact of hospitals can be partly explained by the fact that, in Belgium, pharmaceutical expenditures are largely attributed to hospitals (53.2% in 2022). [4] The high contribution from pharmaceutical products may also be related to the use of EXIOBASE as the EE-MRIO, which assigns relatively high emission intensities to this industry compared with ICIO or FIGARO.
- Compared to other countries, direct and indirect GHG emissions per capita in Belgium (731 kg CO_2 per capita in 2018) were above EU averages (with 560 and 452 kg CO_2 eq for the EU-14 and EU-27, respectively – Based on the OECD model). Belgium ranked the second highest country in the EU in 2018, just after Germany. Expressed as a share of total GHG emissions for all sectors, results are also higher in Belgium (5.5%) than the EU-averages (4.9% for the EU-14 and 4.3% for the EU-27) and Belgium was the fourth highest country in 2018 (after Germany, Denmark and Portugal).
- In conclusion, even if these data should be interpreted with caution, the performance of the Belgian health system concerning its GHG foodprint seems moderate and the modest decline observed in 2022 must be significantly accelerated.

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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 4).

Table 4 – 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 5. 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 5 – 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 6.

Table 6 – 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 7.
   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 7 – 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 8 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 8 below provides an overview of the structure of origin sector groups.

Table 8 – 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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