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Carbon footprint of healthcare systems: a systematic review of evidence and methods

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Carbon footprint of healthcare systems: A systematic review of evidence and methods

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ABSTRACT

Objective: Given the demand for net-zero healthcare, the carbon footprint (CF) of healthcare systems has attracted increasing interest in research in recent years. This systematic review investigates the results and methodological transparency of CF calculations of the healthcare system by using input–output or hybrid analyses.

Design and methods: We systematically searched various databases. We included all health care sectors CF calculations. To facilitate a structured extraction of the relevant methodological items, we developed a tool for data extraction and applied it to all studies that were considered. The main outcome was the CF of the healthcare system and its sources of emissions. A transparency checklist for reporting sector level CFs was developed and applied.

Results: The database search yielded 2,469 studies excluding duplicates, while we finally considered 14 of them. The mean ratio of emissions due to the healthcare system to the total national emissions was 4.9% [minimum 1.5%; maximum 9.8%], and the results of the time series showed a growing footprint in most countries. Hospital care led to the largest relative share of the total CF. At least 71% of the items of each study were reported.

Conclusion: The results of this review show that healthcare systems contribute substantially to national carbon emissions, and hospitals are one of the main contributors in this regard. They also show that mitigation measures can help reduce emissions over time. However, the comparison of results is limited because of methodological heterogeneity and a lack of transparency. The standardized reporting of carbon emissions is necessary to be able

to use these calculations as a basis for decision-making. The checklist developed here can serve as a reference point to help make methodological decisions in future research reports as well as report homogeneous results.

Keywords: life-cycle assessment, input-output, global warming potential

STRENGTHS AND LIMITATIONS OF THE STUDY

- To the best of our knowledge, this is the first study to systematically assess greenhouse gas emissions by healthcare systems.
- The assessment of methodological choices and the transparency of methods when assessing the greenhouse gas emissions of entire sectors in systematic reviews can help deepen our understanding of the results.
- This review was limited to articles in English and German, and excluded assessments, grey literature from public reports, and reports from statistical offices published in other languages.

Word count: 4000

INTRODUCTION

Background

Climate change is one of the most pressing issues of our time [1]. Given the correlation between the gross domestic product (GDP) and carbon emissions [2], the healthcare industry is likely an important contributor to greenhouse gas (GHG) emissions. Demographic changes and income effects have likely increased the demand for healthcare services, where this is likely to continue to increase, and have consequently enhanced the economic importance of the healthcare industry [3]. Evidence on healthcare's emissions is needed to better understand its role.

Methods to calculate the carbon footprint (CF) can be broadly categorized into bottom-up and top-down approaches. Bottom-up methods, such as the process-based lifecycle assessment (LCA) are too demanding of data to be applied at a sectoral level. However, the CF of different sectors can be estimated by accepting the trade-off of a more uncertain top-down methodology. In this case, all emissions are divided according to the final demand sectors or the economic sectors of emission occurrence. Input–output (I–O) analysis, which follows this approach, is used to estimate the CF [4]. Calculations of the CF use the static open-quantity I–O model in combination with an environmental extension. They rely on two fundamental building blocks: an I–O table and a demand vector. The I–O table describes the interactions between the sectors of production, often in monetary terms, and are usually constructed by national statistics offices. The demand vector represents the expenditures of the relevant sectors. For example, the demand vector of the healthcare sector includes expenditure on diesel fuel to power ambulances, electricity consumed by hospitals, and all other forms of energy consumed. It may be necessary to synchronize the structures of the I–O table and the demand vector by balancing the definitions of different sectors and adjusting the level of sectoral aggregation. I–O models can be grouped into single-region I–O (SRIO) and multi-region I–O (MRIO) models. SRIO models use only an I–O table from a single country, and can therefore account for only domestic production and emissions. MRIO models connect multiple I–O tables from multiple countries, and can thus account for different levels of production and "trade" in emissions (i.e., emissions in one country related to the final demand of another country). The need for synchronized data from multiple countries complicates the development and update of the data of MRIO models.

The results of calculations of the CF of a given sector can be affected by methodological choices, such as the decision to use either the SRIO or the MRIO model, and the GHGs considered. Therefore, standardized reporting is needed to ensure the transparency of methodological choices, the data, and the results. However, our search of the literature yielded neither a standardized procedure nor standardized reporting.

Objective

The objective of this study is to systematically review research that has used I–O analysis to calculate the CF of healthcare systems, including the total CF, the CF per capita, and that as a share of the national CF. Furthermore, time series data can help us better understand the trajectory of development of the CF of the healthcare system. As our search of the literature yielded no standardized scheme of reporting the relevant information, we develop a checklist of important elements in the calculation of the CF in our review.

METHODS

Search strategy and selection criteria

This systematic review was performed by following the PRISMA guidelines [5] (the checklist has been provided in the Appendix). The databases PubMed, ISI Web of Science, EconBiz, Scopus, and Google Scholar were searched for studies on November 25, 2019. The search was complemented by reference tracking within all the included studies, and was updated on April 25, 2022.

Following the screening of their titles and abstracts, studies were included for further investigation if they had (i) addressed the CF by using a traceable method of calculation, (ii) addressed the healthcare system or subsystem, and (iii) been written in English or German. A healthcare system was defined as the national healthcare system, federal system, and/or state system. Single entities, such as individual hospitals, and specialized branches, such as dentistry, were excluded. In addition to the criteria used for screening the titles and abstracts of articles, full-text articles were excluded if they (i) did not name the specific healthcare (sub)system, (ii) did not calculate the CF, or (iii) did not provide information on the method of calculation used.

Data extraction and analysis

Data from studies that met the above criteria were extracted and analyzed. Two of the authors separately screened their titles and abstracts, read the full text, and extracted data from them (LF, MH, MKe, MKn, and FW).

We used the CO_2e per capita, the contribution of healthcare to the country's total CO_2e emissions, and the distribution of the origins of these emissions as main results of the studies. to calculate the CF. Furthermore, the breakdown of the CF in scopes, demand categories, or places of origin was extracted. The scope of the CF has been described in the Greenhouse Gas Protocol Corporate Accounting and Reporting Standard [6], in which three standardized scopes have been proposed. Scope 1 represents direct emissions from owned or controlled sources, Scope 2 represents indirect emissions generated by the purchased energy, and Scope 3 represents all indirect emissions that occur in the value chain. The categories of demand included the classes of expenditures of the final demand vector, and the places of the origin of emissions were divided into hospitals, ambulatory services, and so on.

We assessed the methodological transparency of the studies considered in addition to their general characteristics and results. A data extraction tool was developed to report information on the CFs of healthcare systems by using the I–O method. It collected data on the methodological choices, demand vector, data synchronization, and uncertainty analysis in13 items. We calculated the transparency score by combining the five items on the reporting of the results and the 13 items related to the reporting of the methods. These items are summarized in Table 1, and a more detailed description has been provided in the Appendix.

Table 1: Description of the criteria for transparency

	Number	Criteria
System description and results	0 *	System description
	1	Total carbon footprint
	2	Carbon footprint as a share of the total national CF
	3	CF per capita
	4	CF breakdown
Method and transparency	5	LCA method
	6	Source of demand data (detail)
	7	Year of demand data
	8	Number of categories of demand or expenditure
	9	Data source of I–O table
	10	Year of I–O table
	11	Multi-regionality of the model
	12	Number of production sectors
	13	Source of emission data
	14	GHGs considered
	15	Concordance matrix reported
	16	Sensitivity and uncertainty analysis
	17	Discussion of limitations
	** not included in the transparency score*	

RESULTS

A total of 2,317 records were identified in the initial search (Figure 1). Three additional studies were found through reference tracking and the Google Scholar database. Following the removal of 550 duplicates, 1,770 records were obtained, of which 39 titles and abstracts met the criteria for the further investigation of their full texts. Thirty of these studies met the exclusion criteria, and thus nine studies were considered in the review. An update of the search yielded 1,056 studies, of which 358 were duplicates. A total of 665 were excluded during the screening of the title and the abstract, and 29 were excluded following a screening of the full text. One study was identified through reference tracking and a total of five more studies were added in theupdate. A summary of the finally identified studies is provided in Table 2. The form of data collection and the data used for the analysis have been provided in the Appendix.

-Insert figure 1 around here-

Characteristics of the studies considered

Ten of the finally chosen studies had focused on a single national healthcare system, including those in England [7] [8], Japan [9], USA [10] [11], Canada [12], Scotland [13], China [14], Australia [15], and Austria [16]. The series of CFs from the Sustainable Development Unit of the English NHS was aggregated, and only the newest available report was cited. One study had examined the healthcare system of the largest Australian state, New South Wales [17] while three studies had reported on healthcare systems in multiple countries. Pichler, et al. [18] had reported results for 36 countries, Healthcare without Harm (HCH) for 43 countries [19], and the investigation by Lenzen, et al. [20] had considered 189 countries. Excluding the one that had assessed the Scottish NHS, all studies had been published after 2016. However, their demand data, which defined the period of the study, deviated. For example, the study by Nansai et al. (11) had been published in 2020 but had used demand data from 2011 [9]. The number of available categories of demand or expenditure ranged from 13 to 19, with outliers represented by the article by Wu [14] (eight categories), the study on the English NHS [21] (five categories), and work by Malik et al. [15] (nine categories).

Table 2: Characteristics and main results of the studies considered in this review

Author (Year)	Healthcare system	Data year	CF in MT CO2EQ	% of total national CF	tCO_2e/cap	Transparency score
Tennison, et al. 7	England	2018	25	n.i.	0,445	88%
SDU 8	England	2019	25	n.i.	n.i.	71%
Nansai, et al. 9	Japan	2011	72	4,6	0,49	82%
Eckelman and Sherman 10	USA	2013	655	9,8	2,07	85%
Eckelman, et al. 11	USA	2018	554	n.i.	n.i.	76%
Eckelman, et al. 12	Canada	2015	33	5,7	0,92	94%
Scotland 13	Scotland	2004	2,6	3,6	0,52	76%
Wu 14	China	2012	315	2,7	0,23	94%
Malik, et al. 15	Australia	2015	36	7,0	1,50	85%
Weisz, et al. 16	Austria	2014	6,8	7	0,8	94%
Malik, et al. 17	New South Wales, Australia	2017	0,008	6,6	n.i.	71%
Pichler, et al. 18	OECD countries; China, India	2014	s. Appendix	Ø 5,5 s. Appendix	s. Appendix	94%
Karliner, et al. 19	43 countries; EU; rest of the world	2014	s. Appendix	Ø 4,4s. Appendix	s. Appendix	88%
Lenzen, et al. 20	Global	2015	2 290	n.i.	n.i.	88%
* n.i.= not identified						

Differences in methodology and data

Eleven of the studies considered here had used only top-down data on emissions, while three studies had also used bottom-up data on energy usage [7 8 13]. Most single-country studies had used SRIO data from the respective governmental offices, while the studies on British healthcare and those that had considered more than one country had used MRIO data. The most commonly used MRIO database was EORA, one study had used the WIOD database, and two studies had used the MRIO database provided by the British Department for the Environment, Food, & Rural Affairs. The number of production sectors varied, the SRIO studies had considered 178–400 sectors, with the studies by Wu [14] (46 sectors), and Malik, et al. [17] (2,880 sectors) being the outliers. The MRIO studies had used larger databases containing around 15,000 sectors, except the MRIO study on the UK that had considered 424 sectors.

All studies had considered CO_2 emissions. However only four studies had considered the six GHGs covered in the Kyoto protocol, three studies had considered CO_2, methane, and nitrous oxide, two had reported only that they had used CO_2 equivalents, and two studies had not reported any included GHG. The data on emissions had been drawn mostly from national accounts in case of SRIO databases and integrated satellite accounts in case of MRIO databases. One study had not reported the source of its satellite account data.

The demand data had been taken either from national offices and health expenditure accounts, or from international organizations such as the WHO and the World Bank (which itself uses data provided by national offices and accounts). Lenzen, et al. [20] had identified and used data on healthcare-related sectors from the EORA database, where this made it possible to calculate the global time series of the data. The number of reported expenditure accounts varied, but mostly ranged from 13 and 19 accounts, with three studies below this. Weisz, et al. [16] had used nine accounts, Wu [14] had used eight accounts, and the study on the NHS in England had used five accounts [8]. Owing to the different methodology used by Lenzen, et al. [20] as well as the structure of the EORA, which reports country-specific sectors, they had used 163 sectors from the EORA as demand data.

The periods covered by the demand data and the I–O data were mostly consistent. Some studies that had reported time series had used only one reference year for the I–O database, and had adjusted the demand data for inflation [10-12]. The lag between the time at which the data had been collected and the time of publication of the corresponding study ranged from three to six years, with deviations in the studies by Nansai, et al. [9] Eckelman, et al. [11] (two years), and in the report by the SDU [8]. The latter had periodically reported the CF, and the lag between the latest publication and the latest data was one year [8]. Further information on this has been provided in the Appendix.

Reporting of the results

Four studies had reported their concordance matrices, which bridge the categories of demand with the industrial sectors. The authors of one study had made their matrix available upon request, and two articles had referred to a matrix that had been previously used in another study. Five studies did not report their concordance matrices, and 50% of the articles had not normalized the results by reporting the CF per capita. The origins of emissions had been reported five times in the scopes, eight times in the (sub)categories of final demand, and once in the economic sector of emission occurrence one time. Two studies had reported a breakdown of emissions by using more than one reporting structure. Several differences were observed in the reported results in the scopes. Some studies had directly referenced the GHG protocol while others had reported emissions in divisions, such as travel, energy, procurement, and so on.

Overall transparency

Except for the reporting of the concordance matrix, uncertainty analysis, and the CF per capita, all criteria were fulfilled by more than 75% of the studies considered here (Figure 2). The rate of satisfaction of the criteria by each study varied from 70.5% to 94%, with a mean of 85% (Figure 3).

-Insert figure 2 around here-

-Insert figure 3 around here-

OUTCOMES

Time series

The results of the time series revealed successful efforts to mitigate the CF by the NHS in England and Scotland (Figure 4). In the nearly three decades from 1990 to 2019, the English NHS managed to reduce its CF by 25%. The four remaining countries (Japan, Canada, USA, and Australia) examined in the studies considered here as well as the global trend showed an increase in the CF due to healthcare (Figure 4). The annual increase in the CF ranged from 0.7% (USA, 2010–2018) to 3.8% (Japan, 2011–2015) over the observed period, with the CFs of Canada (1.9%, 2009–2015), USA (2.8%, 2011–2015), and Australia (2.9%. 2013–2015) in between these extremes. The global trend showed an increase in the CF of 2.7% per year from 2000 to 2015.

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Breakdown

The sources of emission had been mainly reported by using the scope system from the GHG protocol or the categories of expenditure, i.e., the categories of final demand. The largest dataset that had used the categories of final demand had been provided by Pichler et al. [18], who had applied it to 36 countries and reported the average values. Medical retail, hospitals, and ambulatory healthcare services constituted 80% of the CF of healthcare, with medical retail contributing 33.1%, hospitals responsible for 28.6%, and ambulatory healthcare services at 18%. Medical services thus accounted for 46% of total emissions. They also made a major contribution to the CF in Japan (hospitals, 25.1%; ambulatory services, 22.7%) [9], USA in 2013 (hospital care, 36%; physician and clinical services, 12%) [10] and 2018 (hospital care, 34.9%; physician and clinical services, 12.6%; ambulatory medical services, 4.8%) [12], Australia (public hospitals, 34.4%; private hospitals, 10.2%; ambulatory medical services, 15%) [15], China (public hospitals, 47%; private hospitals, 4%) [14], and Austria (hospitals, 32%; ambulatory services, 18%) [16]. Other important categories of emissions were construction and pharmaceutical products, at around 10% [10 15 18], with a higher share in China (pharmaceuticals, 18%; construction, 15%) [14].

Another approach involved dividing emissions into direct emissions, indirect emissions through electricity production, and other indirect emissions. The division along these lines could also be made by using the three scopes of the GHG protocols. By averaging the data from 43 countries, the HCWH reported a share of 17% for scope 1 emissions, 12% for scope 2 emissions, and 71% for scope 3 emissions [19]. These results, especially the importance of scope 3 emissions, are supported by evidence from the single-country studies [7 10 11 13 21]. The scope 3 emissions were further divided into those due to travel (patient and visitor travel, and staff commutes), production of pharmaceuticals, and medical instruments and equipment, which accounted for the largest share of scope 3 emissions. Scotland's scope 3 travel emissions in 2004 were 18% [13] while those of England accounted for 13% in 2015 [21] and 9.6% in 2018 [8]. The share of emissions owing to pharmaceutical production ranged from 11% and 18%, and that owing to medical instruments and equipment accounted for 7%–10% of the total CF [12 13 21].

The ratio of emissions by the healthcare sector to the total CF in studies that had focused on a single country ranged from 2.7% in China in 2012 [14] to 9.8% in the USA in 2013 [10]. The three cross-national studies considered here had estimated that healthcare had contributed 5.5% [18] on average to the national CF in 2014 and 4.4% in 2015 [20].

DISCUSSION

Interpretation of results

The results indicate that healthcare makes a noteworthy contribution to the CF, both in terms of absolute numbers as well as in relation to the overall emissions of a country and its per capita emissions. However, the results varied among the studies, and their methods of calculation were heterogeneous and frequently not fully transparent. The results of the time series showed that the trend of emissions due to healthcare was positive, i.e., they were increasing, except in Scotland and England. These results are in line with the graphical results provided by Lenzen, et al. [20]. The breakdown of the sources of emissions revealed the major contribution made by hospitals.

To the best of our knowledge, this is the first study to systematically consider research on GHG emissions by healthcare systems and develop a catalogue of transparency for a systematic review of studies on the CFs of different sectors. However, it has several limitations. First, most of the data used here were from the OECD countries, China, and India. The only exception was the work by Lenzen, et al. [20], who considered 189 countries in their analysis [20]. However, even if the distribution of countries limits the representativeness of the results, the findings are consistent with the fact that OECD countries are the main emitters of GHGs. The evidence provided here is further limited by the use of I–O methods in the studies considered because they can introduce uncertainties to the assessment. I–O studies use a top-down approach based on aggregated sectors of the industry. When heterogeneous products of emission with varying production and structures of emission are grouped into one industry, an aggregation error might occur such that the aggregated industry does not appropriately reflect the emissions. This leads to either overestimated (in case of expensive goods that yield lower emissions) or underestimated results (in case of cheap goods that yield higher emissions) [22]. Second, the review process used here was limited due to restrictions on the language used in the study and those related to access. It is possible that several assessments of the CF have been published in the official languages of many countries in the grey literature, such as publications by national statistics offices or governmental agencies. Because this review included only publications in English and German, many such studies have likely been neglected. Third, the reporting scheme and transparency score used in this study had associated limitations. Both were based only on a consensus among the authors. The instruments used to assess the quality of the published studies are typically chosen based on a broad consensus among experts, such as in case of the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) [23].However, we did not find similar guidance for I–O analyses.

The results of the time series showed that the trend of emissions due to healthcare was positive in all the countries considered, i.e., they were increasing, except in Scotland and England. These results are in line with the graphical results provided by Lenzen, et al. [20]. Furthermore, they showed that the efforts of the British NHS systems to reduce their carbon footprint based on the Greener NHS program had been effective in reducing GHG emissions. The breakdown of the sources of emissions verified the important contribution of hospitals. However, hospitals often provide the majority of medical care in many countries. Therefore, their large CF is not a surprising result, but might motivate the relevant authorities to better handle their emissions. The breakdown further showed that a large portion of the CF of healthcare stemmed from scope 3 emissions. Policymakers may find that the greatest reduction in emissions can be obtained by addressing travel by staff and patients. Therefore, "greening" the healthcare sector requires a sustainable transportation system and green healthcare goods.

While heterogeneity in methodology in general can lead to more robust results and a more informative perspective on the issue at hand, the differences in I–O methodologies to calculate the CF of healthcare may reduce the comparability of the results. When computing the CF of an economic sector by using the I–O method, a choice needs to be made between the SRIO and MRIO models. Both offer certain advantages. The MRIO approach is more complete because it captures not only the supply chains within the country in question, but also those in other countries. In particular in small, open economies with a large share of trade, a significant part of total GHG emissions may be "embodied" emissions; i.e., emissions generated by foreign producers during the production of imported goods. A drawback of the MRIO approach is that MRIO tables are sometimes less accurate than SRIO tables because the latter are typically constructed by national statistics offices, which have access to highly detailed (and classified) firm-specific data. On the contrary, MRIO tables are formulated by other organizations that may not have access to such data. Furthermore, MRIO tables are often more aggregated than SRIO tables, which implies a further loss of information compared with the highly disaggregated SRIO tables. Therefore, some researchers prefer the SRIO approach, but this hinders a direct comparison of the results of different studies. Such a comparison may also be hindered by different choices of systemic boundaries or general differences between healthcare systems (e.g., a healthcare service may be included in the data on public healthcare expenditure in one country but excluded from those in another). A standardized approach to setting the boundary of the system may help increase the comparability of future results.

Future research should assess the potential effects of efforts to reduce emissions on the system, and should seek pathways to a low-carbon healthcare system. Finally, future research should examine errors of aggregation when using the I–O methodology in the context of healthcare. Moreover, the differences obtained in the outcomes when making different methodological choices (SRIO or MRIO, systemic boundaries, etc.) should be analyzed to guide future research.

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DECLARATIONS

Author contributors

Mattis Keil: Methodology, Screening, Formal Analysis, Writing – Original Draft, Writing-Review and Editing, Visualization; **Leonie Frehse:** Methodology, Screening, Formal Analysis, Writing – Original Draft; **Marco Hagemeister:** Methodology, Screening, Formal Analysis, Writing – Original Draft **Mona Knieß:** Methodology, Screening, Formal Analysis, Writing – Original Draft **Oliver Lange:** Conceptualization, Methodology, Writing - Review and Editing**, Tobias Kronenberg:** Methodology, Writing – Review and Editing **Wolf Rogowski:** Conceptualizing, Methodology, Writing - Review and Editing, Supervision, Project administration. All authors have read and approved the final manuscript for publication.

Conflict of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data statement

The data that support the findings of this study are available in Appendix 4a "System description and results" and Appendix 4b "Methods and transparency." Further data are available from the corresponding author, [MK], upon reasonable request.

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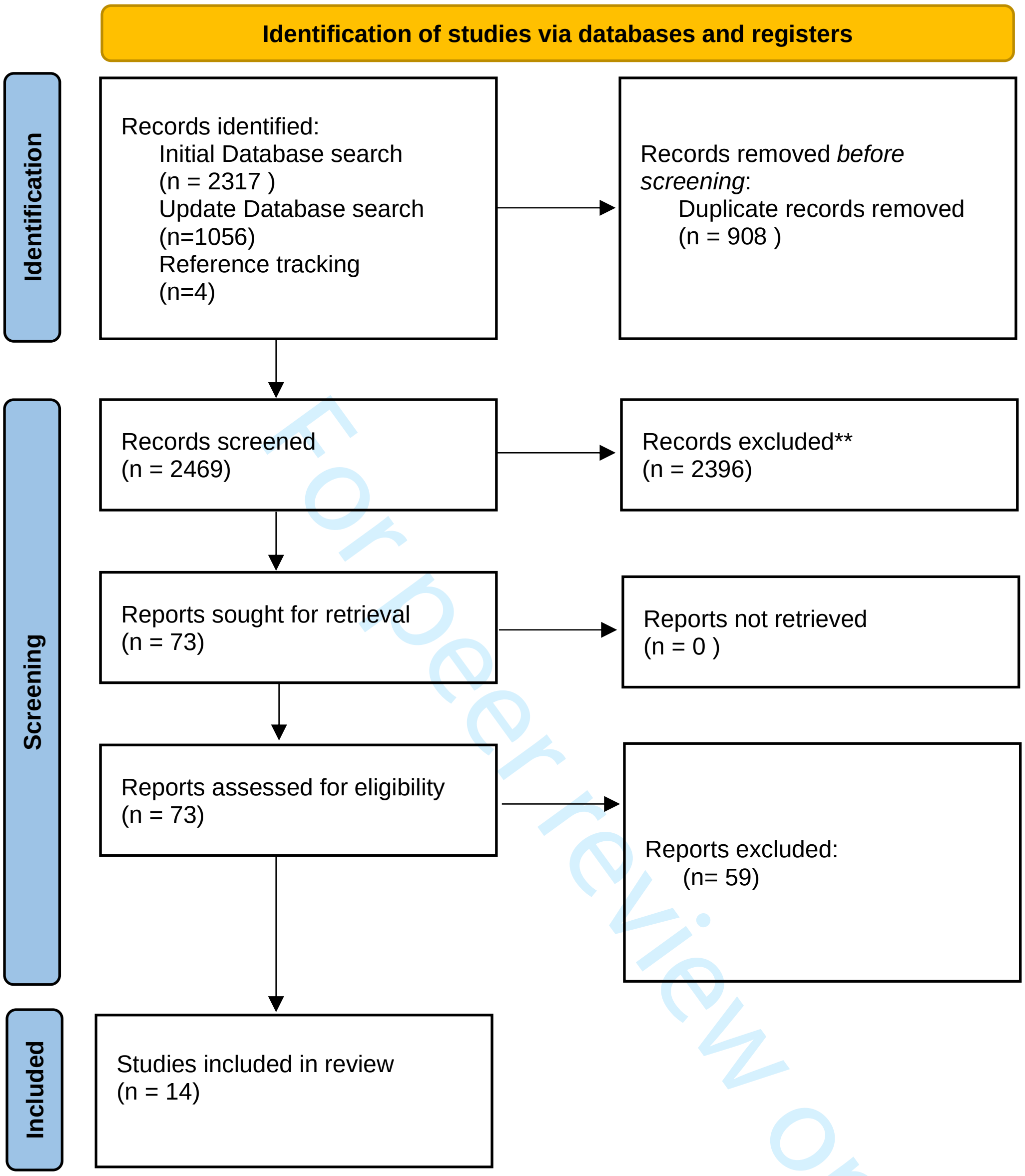

Figure 1: Prisma Flow Diagram, based on Page et al. (2021)

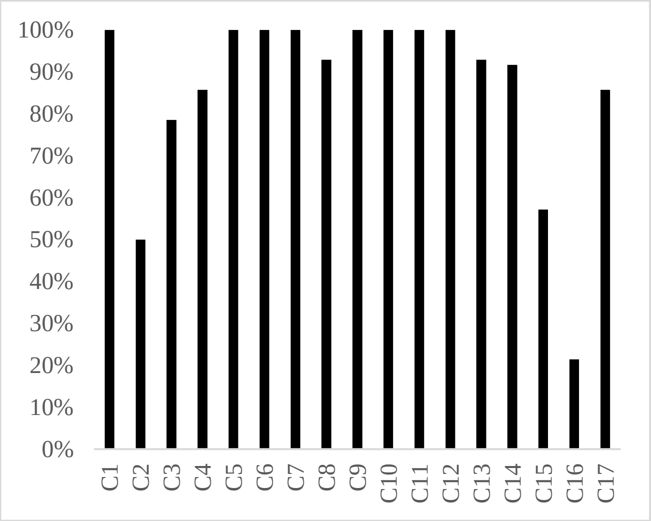

Figure 2: Fulfilment rate of the transparency and reporting criteria

Figure 3: Transparency core in % per article

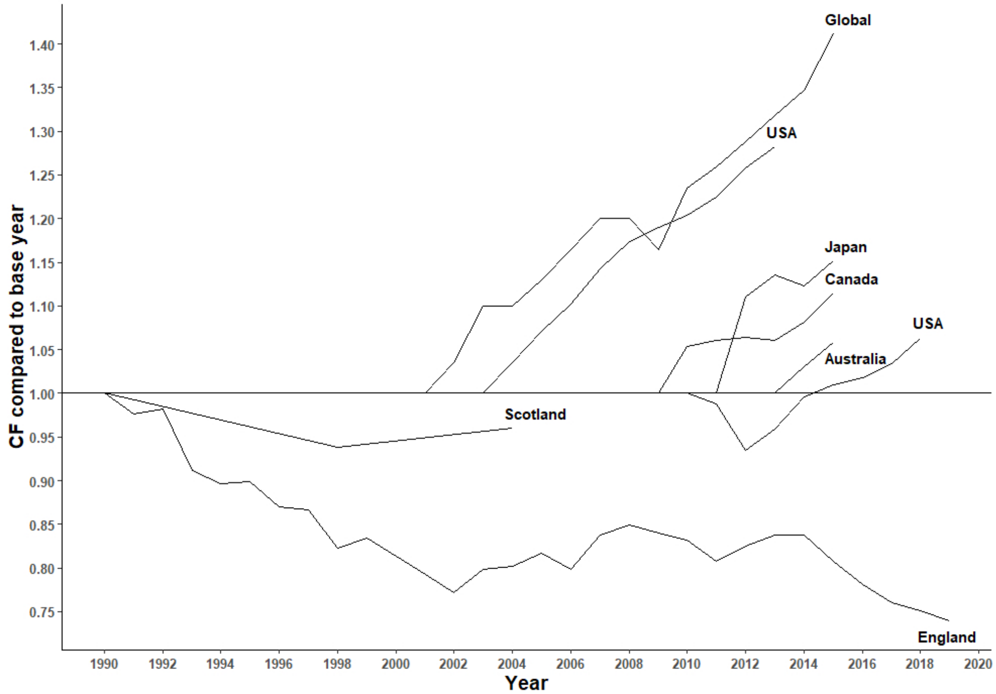

FIgure 4 Time series results

83x59mm (300 x 300 DPI)

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Title, Methods
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page 1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Introduction on Page 3
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Introduction on Page 3
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Methods section on Page 4
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Methods section on Pages 3-4
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Supplementary materials
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Methods section on Page 4
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Methods section on Page 4
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Methods section on Pages 4-5
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Methods section on Pages 4-5
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	n.a.
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Methods section on Page 4
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	n.a.
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	n.a.

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	n.a
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	n.a.
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	n.a.
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	n.a
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	n.a.
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	n.a
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Results on page 5
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	n.a.
Study characteristics	17	Cite each included study and present its characteristics.	Results on pages 5-6
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	n.a.
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Results on pages 6-7
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	n.a.
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	n.a.
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	n.a.
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	n.a.
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	n.a.
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	n.a.
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Discussion on page 8
	23b	Discuss any limitations of the evidence included in the review.	Discussion on page 8
	23c	Discuss any limitations of the review processes used.	Discussion on page 8
	23d	Discuss implications of the results for practice, policy, and future research.	Discussion on page 9

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Page 9
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Page 9
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	n.a.
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Page 10
Competing interests	26	Declare any competing interests of review authors.	Page 10
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Appendix

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

For more information, visit: http://www.prisma-statement.org/

S1: Further description of the transparency criteria

#	Criteria	Further description
System description and results		
0 (not included in the transparency score)	System description	It should be reported which national healthcare system was assessed. Healthcare system was defined, closely to the definition of the WHO as follows: *"A health system consists of organizations, people and actions whose primary intent is to promote, restore or maintain health."*
1	Total Carbon Footprint	The total CF of a healthcare system can help to understand the total impact the system has on climate change
2	Carbon Footprint as a share of the total national CF	The share of healthcare's CF of the total national CF can help to understand the importance of the healthcare system to mitigate the climate impact of a country as well as to analyze systematic differences in the importance of the healthcare systems in mitigating the national CF between countries
3	CF per capita	The CF per capita can help to compare healthcare systems between different-sized countries.
4	CF breakdown	The division of total CFs in scopes or subcategories can help to understand the "hot spots" in GHG emissions within healthcare systems.
Method and Transparency		
5	LCA method	The LCA method can be distinguished between Top-Down (i.e. Using only Input-Output Data), Bottom-Up (i.e. using only Process-based data), and Hybrid (Using both data types). Each type has its advantages and disadvantages and should be reported to enable a first assessment of the used method.
6	Demand Date source (detail)	To avoid inaccurate, outdated, or unfitting data the data source is important to report for transparency.
7	Demand Data year	To avoid inaccurate, outdated, or unfitting data the data year is important to report for transparency.
8	Number of demand or expenditure categories	The number of demand or expenditure categories can help to assess the level of detail in which the healthcare system is modeled. The more expenditure categories are used, the higher the level of detail might be.
9	I-O table data source	Similar to the demand vector, the data source of the I-O table is important to ensure the data quality and transparency
10	I-O table year	Similar to the demand vector the data year of the I-O table is of importance to ensure the data quality and transparency
11	Multiregionality of the model	I-O tables can be distinguished in SRIO, which aggregates the economic sectors of a single country, or MRIO, which aggregates the sectors of multiple countries. As each of the models has its implications it is important to report the model type.
12	Number of production sectors	The number of production sectors within the I-O model can help to estimate the level of aggregation. The more production sectors are used the less aggregated the model might be.

13	Source of emission data	The report of emissions data sources ensures the quality.
14	Included GHGs	The results might vary dependent on the included GHGs with more included GHG leading to a higher CF. This leaves room for
15	Concordance matrix reported	The bridge matrix connects the demand vector with the IO table. Each value in the demand vector, representing a demand from a certain economic sector, has to be connected to one or multiple sectors within the IO table. The bridge matrix defines these connections and makes the connection operationalizable. The bridge matrix can be either presented in matrix form or as a table classifying the demand vector values to IO table sectors.
16	Sensitivity and Uncertainty analysis	Quantitative analysis of uncertainty can add clarity and transparency to uncertainty reporting to the reader. Furthermore, it can help prioritize efforts to improve data quality in those areas of uncertainty which contribute most to the overall uncertainty of the results
17	Discussion of limitations	A variety of limitations can arise from CF calculations with IO models (e.g. insufficient data, high level of aggregation, etc.). Therefore, a critical discussion of limitations can increase transparency.

Full search strategies for all databases

DATABASE	SEARCH TERM
SCOPUS	TITLE-ABS(((footprint OR "carbon emission" OR "greenhouse gas*")) AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR “health services”))) OR ("input-output" AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR “health services”)) AND ((footprint OR "carbon emission" OR "greenhouse gas*" OR environmental* extended))) AND NOT DOCTYPE(ed) AND NOT DOCTYPE(er) AND NOT DOCTYPE(le) AND NOT DOCTYPE(no) AND NOT DOCTYPE(pr)
WEB OF SCIENCE	TOPIC: ((((footprint OR "carbon emission" OR "greenhouse gas*")) AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR “health services”))) OR ("input-output" AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR “health services”)) AND ((footprint OR "carbon emission" OR "greenhouse gas*" OR environmental* extended))))Timespan: All years. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC.
ECONBIZ	(((footprint OR "carbon emission" OR "greenhouse gas*")) AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR “health services”))) OR ("input-output" AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR “health services”)) AND ((footprint OR "carbon emission" OR "greenhouse gas*" OR environmental* extended)))
PUBMED	Search (((footprint OR "carbon emission" OR "greenhouse gas*")) AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR “health services”))) OR ("input-output" AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR “health services”)) AND ((footprint OR "carbon emission" OR "greenhouse gas*" OR environmental* extended)))

Appendix: System description and results

Please use Ctrl + Scroll to zoom in this electronic appendix

Author	Year	Title	Health Care System	Carbon Footprint	tCO2/capita	% of total emission	Breakdown
Nansai et al.	2020	Carbon footprint of Japanese health care services from 2011 to 2015	Japan	2011:62.5mt CO2 equivalent; 2012: 69,4mt CO2eq; 2013: 71 mt CO2eq; 2014 70.2mt CO2eq; 2015 72 mtCO2eq	c.n.	4,6% of the total domestic GHG emission	~Capital vs. Service: Service:86%; Capital formation 14% ~Broad Categories: Fixed Capital Formation: 15.92%; Nursing services 16.16%; Health and Hygiene : 1.3% ; Household medication; 2,4% ; Medical services 66,4% ~Detailed Categories: Medical services (hospitalization): 25.12%; Medical services (non-hospitalization): 22,72%; Medical services (pharmacy dispensing) 13.1%; Home medication: 1.84%; Nursing care (facility services) 6.64% ; Nursing care (excluding facility services): 9,47%; Private fixed capital formation for medical services 10,22%; Private fixed capital formation for nursing care 1.62%
Eckelman et al.	2016	Environmental Impacts of the U.S. Health Care System and Effects on Public Health	USA	2003:511 Mt CO2eq; 2004:529 Mt CO2eq; 2005:547 Mt CO2eq; 2006:563 Mt CO2eq; 2007:584 Mt CO2eq; 2008:600 Mt CO2eq; 2009: 608 Mt CO2eq; 2010:615 Mt CO2eq; 2011:626 Mt CO2eq; 2012:643 Mt CO2eq; 2013:655 Mt CO2eq	c.n.	2003: 7,2%; 2004: 7,3%; 2005: 7,6%; 2006: 7,8%; 2007: 8,0%; 2008: 8,5%; 2009: 9,2%; 2010: 9,0%; 2011: 9,3%; 2012: 9,9%; 2013: 9,8%;	Hospital Care: 36%; Physicians and Clinical Services: 12%; Prescription Drugs: 10%; Other Professional Services: 1,5%; Dental Services:1,6%; Other Health, Residential, Personal Care: 3,8%; Home Health Care: 2,5%; Nursing Care Facilities and Continuing Care Retirement Communities: 6%; Durable Medical Equipment: 2,6%; Other Non-Durable Medical Products: 2,2%; Government Administration: 2,2%; Net Cost Health Insurance: 1,3%; Government Public Health Activities: 4,3 %; Research: 1,6%;Structure and Equipment: 10,4%
Pichler et al.	2019	International comparison of health care carbon footprints	OECD (Australia; Austria; Belgium; Canada; Chile; Czech Republic; Germany; Denmark; Spain; Estonia; Finalnd; France; Great Britain; Greece; Hungary; Ireland; Iceland; Italy; Japan; Korea; Luxemburg; Latvia; Mexico; Netherlands; Norway; Poland; Portugal; Slovakia; Slovenia; Sweden; Turkey; United States; Israel; New Zealand); China; India	~Australia: 19,5 mtCO2e; ~Austria: 6,8 mtCO2e; ~Belgium: 7,5 mtCO2e; ~Canada: 29,7 mtCO2e; ~Chile: 5,9 mtCO2e; ~China: 600,6 mtCO2e; ~Czech Republic: 4,8 mtCO2e; ~Germany: 55,1 mtCO2e; ~Denmark: 4 mtCO2e; ~Spain: 19,2 mtCO2e; ~Estonia: 1,2 mtCO2e; ~Finland: 3,9 mtCO2e; ~France: 34,4 mtCO2e; ~Great Britain: 41,1 mtCO2e; ~Greece: 4,2 mtCO2e; ~Hungary: 2,9 mtCO2e; ~India: 74,1 mtCO2e; ~Ireland: 3,1 mtCO2e; ~Iceland: 0,2 mtCO2e; ~Italy: 23,1 mtCO2e; ~Japan: 114,9 mtCO2e; ~Korea: 33,1 mtCO2e; ~Luxemburg: 0,7 mtCO2e; ~Latvia: 0,5 mtCO2e; ~Mexico: 16,6 mtCO2e; ~Netherlands: 15,8 mtCO2e; ~Norway: 3,6 mtCO2e; ~Poland: 17,4 mtCO2e; ~Portugal: 4 mtCO2e; ~Slovakia: 4,1 mtCO2e; ~Slovenia: 0,7 mtCO2e; ~Sweden: 4,1 mtCO2e; ~Turkey: 17,8 mtCO2e; ~United States: 479,7 mtCO2e; ~Israel(2013): 3,5 mtCO2e; ~New Zealand (2017):1,8 mtCO2e	~Australia: 0.83 tCO2/cap; ~Austria: 0,8 tCO2/cap; ~Belgium: 0,66 tCO2/cap; ~Canada: 0,83 tCO2/cap; ~Chile: 0,73 tCO2/cap; ~China:0,44 tCO2/cap; ~Czech Republic: 0,46 tCO2/cap; ~Germany: 0,68 tCO2/cap; ~Denmark: 0,71 tCO2/cap; ~Spain: 0,41 tCO2/cap; ~Estonia: 0,88 tCO2/cap; ~Finland: 0,72 tCO2/cap; ~France: 0,52 tCO2/cap; ~Great Britain: 0,64 tCO2/cap; ~Greece: 0,39 tCO2/cap; ~Hungary: 0,29 tCO2/cap; ~India: 0,06 tCO2/cap; ~Ireland:0,68 tCO2/cap; ~Iceland: 0,61 tCO2/cap; ~Italy: 0,38 tCO2/cap; ~Japan: 0,9 tCO2/cap; ~Korea: 0,65 tCO2/cap; ~Luxemburg: 1,24 tCO2/cap; ~Latvia: 0,26 tCO2/cap; ~Mexico: 0,13 tCO2/cap; ~Netherlands: 0,93 tCO2/cap; ~Norway: 0,7 tCO2/cap ; ~Poland: 0,46 tCO2/cap; ~Portugal: 0,38 tCO2/cap; ~Slovakia: 0,75 tCO2/cap; ~Slovenia:0,35 tCO2/cap; ~Sweden: 0,42 tCO2/cap; ~Turkey: 0,23 tCO2/cap; ~United States: 1,51 tCO2/cap ; ~Israel(2013):0,43 tCO2/cap; ~New Zealand (2017):0,42 tCO2/cap	~Australia: 4,2%; ~Austria: 6,7%; ~Belgium: 7,7%; ~Canada:5,1%; ~Chile:5,9%; ~China: 6,6%; ~Czech Republic: 4,5%; ~Germany: 6,7%; ~Denmark:6,4%; ~Spain: 5,5%; ~Estonia: 5,2%; ~Finland: 5,3%; ~France: 6,9%; ~Great Britain: 5,9%; ~Greece: 3,8%; ~Hungary: 5,4%; ~India: 3,5%; ~Ireland: 6,7%; ~Iceland: 4,7%; ~Italy: 5,1%; ~Japan: 7,6%; ~Korea: 5,3%; ~Luxemburg: 3,6%; ~Latvia: 3,9%; ~Mexico:3,3%; ~Netherlands: 8,1%; ~Norway: 4,7%; ~Poland: 5,7%; ~Portugal:6%; ~Slovakia:6,7%; ~Slovenia: 4%; ~Sweden: 4,5%; ~Turkey: 3,9%; ~United States: 7,9%; ~Israel(2013): 4,4%; ~New Zealand (2017):4,1%	~Public health care: 62%; Private health care: 31%; Investment: 6% ~Broad Categories: Medical retail: 33%; Hospital; 28,6%; ambulatory health care services:18%; Others: 20%; ~Detailed Categories: Hospital Care: 2003: 184 (Mt CO2-e); 2004: 188; 2005: 195; 2006: 200; 2007: 206; 2008: 210; 2009: 218; 2010: 222; 2011: 226; 2012: 233; 2013: 238; Physician and Clinical Services: 2003: 57; 2004: 60; 2005: 65; 2007:68; 2008: 68; 2009: 69; 2010: 70; 2011: 72; 2012: 74; 2013: 77; Other Professional Services: 2003: 7; 2004: 8; 2005: 8; 2006: 8; 2007: 8; 2008: 8; 2009: 9; 2010: 9; 2011: 9; 2012:10; 2013:10; Dental Services: 2003: 11; 2004: 12; 2005: 12; 2006: 12; 2007:12; 2008: 12; 2009: 12; 2010: 12; 2011: 12; 2012:12; 2013: 11; Other Health, Residential, and Personal Care: 2003: 20; 2004: 21; 2005: 22; 2006: 22; 2007: 23; 2008: 23; 2009: 24; 2010: 25; 2011: 25; 2012:25; 2013: 26; Home Health Care: 2003: 9; 2004: 10; 2005: 11; 2006: 12; 2007: 13; 2008: 13; 2009: 14; 2010: 15; 2011: 15; 2012: 16; 2013: 17; Nursing Care Facilities and Continuing Care Retirement Communities: 2003: 35; 2004: 36; 2005: 37; 2006: 37; 2007: 38; 2008: 39; 2009: 39; 2010: 39; 2011: 40; 2012: 40; 2013: 41; Prescription Drugs: 2003: 59; 2004: 63; 2005: 65; 2006: 68; 2007: 71; 2008: 71; 2009: 72; 2010: 69; 2011: 68; 2012: 67; 2013: 68; Durable Medical Equipment: 2003: 12; 2004:13; 2005: 14; 2006: 15; 2007: 16; 2008: 16; 2009: 16; 2010: 16; 2011: 17; 2012: 17; 2013: 18; Other Non-Durable Medical Products: 2003: 11; 2004: 11; 2005: 12; 2006: 12; 2007: 13; 2008: 13; 2009: 13; 2010: 13; 2011: 14; 2012: 15; 2013: 15; Government Administration: 2003: 13; 2004: 13; 2005: 14; 2006: 13; 2007: 13; 2008: 13; 2009: 13; 2010: 13; 2011: 14; 2012: 14; 2013: 15; Net Cost of Health Insurance: 2003: 7; 2004: 7; 2005: 7; 2006: 8; 2007: 8; 2008: 8; 2009: 8; 2010: 8; 2011: 8; 2012: 8; 2013:9; Government Public Health Activities: 2003: 28; 2004: 28; 2005: 28; 2006: 28; 2007: 29; 2008:30; 2009: 31; 2010: 31; 2011: 29; 2012:29; 2013: 29; Research: 2003: 12; 2004: 12; 2005: 13; 2006: 12; 2007: 12; 2008: 12; 2009: 12; 2010: 13; 20111: 12; 2012: 12; 2013: 11; Structures and Equipment: 2003: 45; 2004: 47; 2005: 50; 2006: 51; 2007: 57; 2008: 62; 2009: 59; 2010: 60; 2011: 65; 2012: 70; 2013: 71;
Eckelman et al.	2018	Life cycle environmental emissions and health damages from the Canadian healthcare system: An economic-environmental-epidemiological analysis	Canada	2009:29,6million Mt CO2e; 2010: 31,2; 2011: 31,4; 2012:31,5; 2013:31,4; 2014:32,0; 2015:33,0;	2014: 0.9; n.c.	2014: 4,6%; n.c.	Hospitals (Private): 2009: 0,7 million Mt CO2e; 2010: 0,7; 2011: 0,7; 2012: 0,7; 2013: 0,7; 2014: 0,8; 2015: 0,8; Hospitals (Public): 2009: 6,5; 2010: 6,8; 2011: 7,0; 2012: 7,0; 2013: 7,1; 2014: 7,1; 2015: 7,1; Other Institutions (Private): 2009: 0,7; 2010: 0,7; 2011: 0,7; 2012: 07; 2013: 0,8; 2014: 0,8; 2015: 0,9; Other Institutions (Public): 2009: 1,1; 2010: 1,2; 2011: 1,2; 2012: 1,2; 2013: 1,2; 2014: 1,2; 2015: 1,3; Physicians: 2009: 3,7; 2010: 3,9; 2011: 4,0; 2012: 4,1; 2013: 4,2; 2014: 4,3; 2015: 4,4; Dental Services: 2009: 1,7; 2010: 1,7; 2011: 1,6; 2012: 1,7; 2013: 1,7; 2014: 1,7; 2015: 1,8; Vision Care Services: 2009: 0,6; 2010: 0,5; 2011: 0,5; 2012; 0,5; 2013: 0,5; 2014: 0,5; 2015. 0,6; Other: 2009: 0,4; 2010: 0,4; 2011: 0,4; 2012: 0,5; 2013: 0,5; 2014: 0,5; 2015: 0,6; Prescribed Drugs: 2009: 6,3; 2010: 6,9; 2011: 6,8; 2012: 6,7; 2013: 6,7; 2014: 6,8; 2015: 7,0; Nonprescribed Drugs: 2009: 1,2; 2010: 1,2; 2011:1,2; 2012: 1,2; 2013: 1,2; 2014: 1,2; 2015: 1,3; Capital: 2009: 2,5; 2010: 2,8; 2011: 2,7; 2012: 2,7; 2013: 2,3; 2014: 2,3; 2015: 2,4; Public Health: 2009: 1,6; 2010: 1,6; 2011: 1,7; 2012: 1,7; 2013: 1,7; 2014: 1,8; 2015: 1,9; Administration: 2009: 0,7; 2010: 0,7; 2011: 0,7; 2012: 0,7; 2013: 0,7; 2014: 0,7; 2015: 0,6; Health Research: 2009: 0,4; 2010: 0,4; 2011: 0,4; 2012: 0,4; 2013: 0,4; 2014: 0,4; 2015: 0,4; Other: 2009: 1,6; 2010: 1,7; 2011: 1,7; 2012: 1,7; 2013: 1,7; 2014: 1,8; 2015: 2,0;
Malik et al.	2018	The carbon footprint of Australian health care	Australia	~2013: 33.796 kt CO2e(0,034mt co2e); ~2014: 34.840 kt CO2 (0,035 co2e); ~2015: 35.772 kt CO2e (0,036 co2e) ;	c.n.	7%	~2013: Public Hospital 34,59%; Private Hospitals 9,62%; All other medications 9,25%; Benefit paid Pharmaceuticals 9,81%; Capital expenditures (Buildings) 7,61%; Referred medicals services 5,88%; Community Health and other 5,29%; General Practice 4,21%; Dental services 3,28%; Aids and Appliances 2,88%; Other health practitioner 2,23%; Research 2,1%; Administration 1,3%; Patient Transport Services 1,16%; Public Health 0,83%; ~2014: Public Hospital 34,35%; Private Hospitals 9,79%; All other medications 9,21%; Benefit paid Pharmaceuticals 9,61%; Capital expenditures (Buildings) 7,72%; Referred medicals services 5,99%; Community Health and other 5,25%; General Practice 4,2%; Dental services 3,22%; Aids and Appliances 2,97%; Other health practitioner 2,16%; Research 2,16%; Administration 1,39%; Patient Transport Services 1,16%; Public Health 0,82%; ~2015: Public Hospital 34,36%; Private Hospitals 10,16%; All other medications 9,35%; Benefit paid Pharmaceuticals 9,1%; Capital expenditures (Buildings) 7,76%; Referred medicals services 6,06%; Community Health and other 5,16%; General Practice 4,22%; Dental services 3,31%; Aids and Appliances 2,95%; Other health practitioner 2,16%; Research 1,94%; Administration 1,43%; Patient Transport Services 1,19%; Public Health 0,82%;
Wu	2019	The carbon footprint of the Chinese health-care system: an environmentally extended input-output and structural path analysis study	China	315 Mt CO2e	0,2	2,70%	~Hospitals 51%; Public Hospitals 47%; Private Hospitals 4%; ~NHP pharmaceuticals 18% ~Community health care 10% ~Public Health 4% ~Other health-care institutions 1% ~Construction 15% ~Research 0,3% ~Administration 0,7%
NHSScotland	2008	National Health Service Scotland Carbon Footprint of NHS Scotland(1990-2004)	Scotland	~1998: 2,74 mt CO2e; ~1998: 2,57 mt CO2e; ~2004: 2,63 mt CO2e	c.n.	3,60%	~Scotland: ~1990: ~Travel 23,73%: Patient own travel 10,95%; Visitor Travel 4,75%; Staff Commuting 2,19%; NHS Travel business 6,21%; ~Building Energy Use 34,31%: Grid-supplied electricity 7,3%; On-site fossil fuel gas 6,94%; On-site fossil fuel oil 10,95%; On-site fossil fuel coal 8,76%; Renewables n.d.; ~Procurement 41,98%: Pharmaceuticals 12,41%; Medical Instruments/equipment 5,48%; Health Services 5,11%; Freight Transport 0,37%; Business Services 3,65%; Paper Products 3,29%; Other Manufactured Products 2,56%; Manufactured fuels, chemical, glasses 1,83%; Food and catering 2,92%; Construction 1,46%; Information and Communication technologies 0,73%; Water and Sanitation 0,73%; Waste products and recycling 0,37%; Other Procurement 1,1%; ~1998: ~Travel 27,63%: Patient own travel 12,84 %; Visitor Travel 5,84%; Staff Commuting 2,72%; NHS Travel business 5,84%; ~Building Energy Use 26,07%: Grid-supplied electricity 8,56%; On-site fossil fuel gas 12,06%; On-site fossil fuel oil 4,28%; On-site fossil fuel coal 1,17%; Renewables n.d.; ~Procurement 46,30%: Pharmaceuticals 14,4%; Medical Instruments/equipment 7%; Health Services 4,67%; Freight Transport 0,39%; Business Services 4,67%; Paper Products 3,5%; Other Manufactured Products 2,33%; Manufactured fuels, chemical, glasses 1,56%; Food and catering 2,33%; Construction 1,95%; Information and Communication technologies 0,78%; Water and Sanitation 0,78%; Waste products and recycling 0,39%; Other Procurement 1,56; ~2004: ~Travel 24%: Patient own travel 10%; Visitor Travel 6%; Staff commuting 3%; NHS travel business 6%; ~Building Energy Use 23%; Grid-supplied Electricity 9%; On-site fossil fuels gas 12%; On-site fossil fuels oil 2%; On-site fossil fuels coal 0%; Renewables 0%; ~Procurement 52%; Pharmaceuticals 18%; Medical instruments/equipment 7%;Health Services 6%; Freight Transport 0%; Business Services 5%; Paper Products 4%; Other manufactured products 3%; Manufactured fuels, chemicals, glasses 2%; Food and catering 2%; Construction 2%; Information and Communication Technology 1%; Water and Sanitation 1%; Waste Products and Recycling 0%; Other Procurement 1%; ~England 2004: ~Travel 18%: Patient own travel 8%; Visitor Travel 2%; Staff Commuting 4%; NHS Travel business 4%; ~Building Energy Use 22%: Grid-supplied electricity 12%; On-site fossil fuel gas 9%; On-site fossil fuel oil 1%; On-site fossil fuel coal 0%; Renewables 0%; ~Procurement 59%: Pharmaceuticals 12%; Medical Instruments/equipment 12%; Health Services 5%; Freight Transport 4%; Business Services 5%; Paper Products 5%; Other Manufactured Products 3%; Manufactured fuels, chemical, glasses 3%; Food and catering 2%; Construction 2%; Information and Communication technologies 2%; Water and Sanitation 1%; Waste products and recycling 1%; Other Procurement 1%
SDU series	2016	Carbon update for the health and care sector in England 2015(1)	NHS England	~1992: 16.58 Mt CO2 ~1993: 15.46 Mt CO2 ~1994: 15.52 Mt CO2 ~1995: 15.48 Mt CO2 ~1996: 15.93 Mt CO2 ~1997: 15.40 Mt CO2 ~1998: 15.77 Mt CO2 ~1999: 16.62 Mt CO2 ~2000: 16.51 Mt CO2 ~2001: 17.97 Mt CO2 ~2002: 17.33 Mt CO2 ~2003: 18.36 Mt CO2 ~2004: 18.62 Mt CO2 ~2007: 21.2 Mt CO2 ~2012: 25 Mt CO2 ~2014: 24.7 Mt CO2 ~2015: 26,6 Mt CO2 ~2017: 27,119 Mt CO2	c.n.	c.n.	~Building Energy Use 18%; ~Travel 13%; ~Commissioned health and care services from outside system 11%; ~Procurement 57%: Pharmaceuticals (excluding Meter Dose Inhalers) 11%; Business Services 11%; Medical Instruments/Equipment 10%; Food and Catering 5%; Freight Transport 3%; Meter Dose Inhalers 3%; Construction 2%; Manufactured fuels, chemicals and glasses 2%; Paper Products 2%; Waste Products and Recycling 2%; Anaesthetic gases 2%; Other manufactured products 2%, Information and communication Technology 2%; Water and Sanitation 1%
HCH	2019	Health Care´s Climate Footprint	Global; Australia; Austria; Belgium; Brazil; Bulgaria; Canada; China; Croatia; Cyprus; Czech Repub-lic; Denmark; Estonia; Finland; France; Germany; Greece; Hungary; India; Indonesia; Ireland; Italy; Japan; Latvia; Lithuania; Luxembourg; Malta; Mexico; Netherlands; Norway; Poland; Portugal; Romania; Russia; Slovak Republic; Slovenia; Spain; South Korea; Sweden; Switzer-land; Taiwan; Turkey; United Kingdom; United States; Rest-of-World; European Union	Global 2 Gt United States 546.54 Mt; China 342.46Mt; European Union 248.52Mt; Japan 103.55Mt; Russian Federation 76.46Mt; Germany 57.51Mt; Brazil 43.84Mt; United Kingdom 42.5Mt; India 38.8Mt; South Korea 37.26Mt; Canada 35.96Mt; Australia 30.17Mt; France 28.98Mt; Mexico 22.53Mt; Italy 21.31Mt; Spain 16.72Mt; Turkey 14.83Mt; Indonesia 13.59Mt; Netherlands 13.32Mt; Poland 13.02Mt; Taiwan 12.27Mt; Belgium 9.3Mt; Switzerland 8.32Mt; Austria 5.04Mt; Sweden 4.5Mt; Denmark 4.4Mt; Greece 4.15Mt; Czech Republic 3.71Mt; Portugal 3.61Mt; Finland 3.51Mt; Romania 3.08Mt; Norway 3.08Mt; Ireland 2.83Mt; Bulgaria 2.7Mt; Hungary 2.55Mt; Slovak Republic 1.19Mt; Slovenia 0.93Mt; Estonia 0.86Mt; Croatia 0.8Mt; Lithuania 0.5Mt; Latvia 0.5Mt; Luxembourg 0.47Mt; Cyprus 0.34Mt; Malta 0.2Mt	Global 0,28 t CO2e; Australia 1,29 tCO2e; Austria 0,59 tCO2e; Belgium 0,83 tCO2e; Brazil 0,21 tCO2e; Bulgaria 0,37 tCO2e; Canada 1,01 tCO2e; China 0,25 tCO2e; Croatia 0,19 tCO2e; Cyprus 0,3 tCO2e; Czech Republic 0,35 tCO2e; Denmark 0,78 tCO2e; Estonia 0,66 tCO2e; Finland 0,64 tCO2e; France 0,44 tCO2e; Germany 0,71 tCO2e; Greece 0,38 tCO2e; Hungary 0,26 tCO2e; India 0,03 tCO2e; Indonesia 0,05 tCO2e; Ireland 0,61 tCO2e; Italy 0,35 tCO2e; Japan 0,81 tCO2e; Latvia 0,25 tCO2e; Lithuania 0,17 tCO2e; Luxembourg 0,84 tCO2e; Malta 0,45 tCO2e; Mexico 0,18 tCO2e; Netherlands 0,79 tCO2e; Norway 0,64tCO2e; Poland 0,34 tCO2e; Portugal 0,35 tCO2e; Romania 0,15 tCO2e; Russia 0,53 tCO2e; Slovak Republic 0,22 tCO2e; Slovenia 0,45 tCO2e; Spain 0,36 tCO2e; South Korea 0,73 tCO2e; Sweden 0,46 tCO2e; Switzerland 1,02 tCO2e; Taiwan 0,52 tCO2e; Turkey 0,19 tCO2e; United Kingdom 0,66 tCO2e; United States 1,72 tCO2e; Rest-of-World 0,16 tCO2e; European Union 0,49 tCO2e;	United States 7,6; China 3,1; European Union 4,7; Japan 6,4; Russian Federation 4; Germany 5,2; Brazil 4,4; United Kingdom 5,4; India 1,5; South Korea 5,3; Canada 5,2; Australia 5,1; France 4,6; Mexico 3,4; Italy 4; Spain 4,5; Turkey 3,2; Indonesia 1,9; Netherlands 5,9; Poland 3,7; Taiwan 4,6; Belgium 5,5; Switzerland 6,7; Austria 5,2; Sweden 4,4; Denmark 6,3; Greece 3,7; Czech Republic ;3,6 Portugal 4,8; Finland 5; Romania 2,7; Norway 4,3; Ireland 4,4; Bulgaria 6; Hungary 4,3; Slovak Republic 2,8; Slovenia 4,6; Estonia 4,7; Croatia 3,2; Lithuania 2; Latvia 3,2; Luxembourg 3,7; Cyprus 2,9; Malta 4,8; Global 4,4%	~~Scopes ~Global 2,0 gt CO2e: ~Health care facilities and health care owend vehicles 17%; Indirect Emissions 12%; Procurement 71%; ~Australia: Scope1 19%; Scope2 9%; Scope3 72%; ~Austria: Scope1 7%; Scope2 6%; Scope3 87%; ~Belgium: Scope1 11%; Scope2 9%; Scope3 80%; ~Brazil: Scope1 21%; Scope2 6%; Scope3 73%; ~Bulgaria: Scope1 6%; Scope2 43%; Scope3 51%; ~Canada: Scope1 26%; Scope2 13%; Scope3 61%; ~China: Scope1 13%; Scope2 7%; Scope3 80%; ~Croatia: Scope1 17%; Scope2 12%; Scope3 71%; ~Cyprus: Scope1 6%; Scope2 16%; Scope3 78%; ~Czech Republic: Scope1 12%; Scope2 5%; Scope3 83%; ~Denmark: Scope1 12%; Scope2 8%; Scope3 80%; ~Estonia: Scope1 6%; Scope2 51%; Scope3 43%; ~Finland: Scope1 5%; Scope2 13%; Scope3 82%; ~France: Scope1 12%; Scope2 5%; Scope3 83%; ~Germany: Scope1 16%; Scope2 18%; Scope3 66%; ~Greece: Scope1 14%; Scope2 24%; Scope3 62%; ~Hungary: Scope1 16%; Scope2 13%; Scope3 71%; ~India: Scope1 8%; Scope2 11%; Scope3 81%; ~Indonesia: Scope1 16%; Scope2 8%; Scope3 76%; ~Ireland: Scope1 13%; Scope2 9%; Scope3 78%; ~Italy: Scope1 9%; Scope2 8%; Scope3 83%; ~Japan: Scope1 16%; Scope2 17%; Scope3 67%; ~Latvia: Scope1 16%; Scope2 8%; Scope3 76%; ~Lithuania: Scope1 19%; Scope2 9%; Scope3 72%; ~Luxembourg: Scope1 14%; Scope2 4%; Scope3 82%; ~Malta: Scope1 7%; Scope2 11%; Scope3 82%; ~Mexico: Scope1 18%; Scope2 34%; Scope3 48%; ~Netherlands: Scope1 12%; Scope2 5%; Scope3 83%; ~Norway: Scope1 12%; Scope2 4%; Scope3 84%; ~Poland: Scope1 12%; Scope2 31%; Scope3 57%; ~Portugal: Scope1 12%; Scope2 5%; Scope3 83%; ~Romania: Scope1 12%; Scope2 10%; Scope3 78%; ~Russia: Scope1 7%; Scope2 31%; Scope3 62%; ~Slovak Republic: Scope1 20%; Scope2 4%; Scope3 76%; ~Slovenia: Scope1 11%; Scope2 12%; Scope3 77%; ~Spain: Scope1 12%; Scope2 5%; Scope3 83%; ~South Korea: Scope1 12%; Scope2 13%; Scope3 75%; ~Sweden: Scope1 12%; Scope2 5%; Scope3 83%; ~Switzerland: Scope1 10%; Scope2 5%; Scope3 85%; ~Taiwan: Scope1 11%; Scope2 26%; Scope3 63%; ~Turkey: Scope1 2%; Scope2 15%; Scope3 83%; ~United Kingdom: Scope1 12%; Scope2 5%; Scope3 83%; ~United States: Scope1 21%; Scope2 15%; Scope3 64%; ~Rest-of-World: Scope1 %; Scope2 %; Scope3 %; ~European Union: Scope1 14%; Scope2 11%; Scope3 75% ~~Economic Sectors: Generation and distribution of electricity, gas and heat or cooling 40%; Health care facilities operational emissions 13%; Other manufacturing 11%; Agruculture 9%; Other sectors and services 8%; Transport 7%; Pharmaceutical and chemical products 5%; Waste treatment 3%; Other primary Industry 3%
Weisz et al.	2020	Carbon emission trends and sustainability options in Austrian health care	Austria	6.8 Mt CO2eq	0.8t	7%	Hospitals 32%; Investments 9%; Medical retail 20%; Other 20%; Ambulatory 18%
Malik et al.	2021	Environmental impacts of Australia's largest health system	New South Wales, Australia	7908t CO2eq	c.n.	6,6%	-
Eckelman et al.	2020	Health Care Pollution And Public Health Damage In The United States: An Update	USA	2010: 520.5Mt CO2eq; 2011: 514.2 CO2eq; 2012: 486.6 CO2eq; 2013; CO2eq; 2014: 518.6 CO2eq; 2015: 525.6 CO2eq; 2016: 529.8 CO2eq; 2017: 538.1 CO2eq; 2018: 553.5 CO2eq	c.n.	c.n.	~~NHE expenditure categories: ~2010: Hospital care: 35.64%; Physician and Clinical Services: 11.47%; Other Professional Services: 2.21%; Dental Services: 3.05%; Other Health, Residential, and Personal Care: 6.72%; Home Health Care: 1.73%; Nursing Home Facilities and Continuing Care Retirement Communities: 6.99%; Prescription Drugs: 11.41%; Durable Medical Equipment: 1.77%; Other Non-Durable Medical Products: 2.46%; Federal Administration Expenditures: 1.44%; State and Local Administration Expenditures: 0.56%; Net Cost of Health Insurance: 1.31%; Public Health Activity: 5.05%; Research: 2.07%; Structures and Equipment: 6.11% ~2011: Hospital care: 35.57%; Physician and Clinical Services: 11.65%; Other Professional Services: 2.26%; Dental Services: 3.01%; Other Health, Residential, and Personal Care: 6.55%; Home Health Care: 1.79%; Nursing Home Facilities and Continuing Care Retirement Communities: 6.94%; Prescription Drugs: 11.09%; Durable Medical Equipment: 1.85%; Other Non-Durable Medical Products: 2.57%; Federal Administration Expenditures: 1.54%; State and Local Administration Expenditures:0.60%; Net Cost of Health Insurance: 1.24%; Public Health Activity: 4.80%; Research: 2.00%; Structures and Equipment: 6.59% ~2012: Hospital care: 35.64%; Physician and Clinical Services: 11.73%; Other Professional Services: 2.26%; Dental Services: 2.92%; Other Health, Residential, and Personal Care: 6.62%; Home Health Care: 1.81%; Nursing Home Facilities and Continuing Care Retirement Communities: 6.76%; Prescription Drugs: 10.81%; Durable Medical Equipment: 1.85%; Other Non-Durable Medical Products: 2.57%; Federal Administration Expenditures: 1.54%; State and Local Administration Expenditures:0.58%; Net Cost of Health Insurance: 1.27%; Public Health Activity: 4.81%; Research: 1.85%; Structures and Equipment: 6.99% ~2013: Hospital care: 35.73%; Physician and Clinical Services: 11.76%; Other Professional Services: 2.24%; Dental Services: 2.81%; Other Health, Residential, and Personal Care: 6.67%; Home Health Care 1.84%; Nursing Home Facilities and Continuing Care Retirement Communities: 6.71%; Prescription Drugs: 10.46%; Durable Medical Equipment: 1.86%; Other Non-Durable Medical Products: 2.59%; Federal Administration Expenditures: 1.6%; State and Local Administration Expenditures: 0.64%; Net Cost of Health Insurance: 1.34%; Public Health Activity: 4.73%; Research: 1.72%; Structures and Equipment: 7.25% ~2014: Hospital care: 35.27%; Physician and Clinical Services: 11.9%; Other Professional Services: 2.28%; Dental Services: 2.7%; Other Health, Residential, and Personal Care: 6.52%; Home Health Care 1.87%; Nursing Home Facilities and Continuing Care Retirement Communities: 6.46%; Prescription Drugs: 11.61%; Durable Medical Equipment: 2.06%; Other Non-Durable Medical Products: 2.7%; Federal Administration Expenditures: 1.72%; State and Local Administration Expenditures: 0.69%; Net Cost of Health Insurance: 1.33%; Public Health Activity: 4.69%; Research: 1.58%; Structures and Equipment: 6.61% ~2015: Hospital care: 34.84%; Physician and Clinical Services: 12.04%; Other Professional Services: 2.25%; Dental Services: 2.59%; Other Health, Residential, and Personal Care: 6.6%; Home Health Care1.86%; Nursing Home Facilities and Continuing Care Retirement Communities: 6.18%; Prescription Drugs: 12.27%; Durable Medical Equipment: 2.05%; Other Non-Durable Medical Products: 2.74%; Federal Administration Expenditures: 1.73%; State and Local Administration Expenditures: 0.65%; Net Cost of Health Insurance: 1.29%; Public Health Activity: 4.74%; Research: 1.48%; Structures and Equipment: 6.66% ~2016: Hospital care: 35.05%; Physician and Clinical Services: 12.31%; Other Professional Services:2.27%; Dental Services: 2.57%; Other Health, Residential, and Personal Care: 6.61%; Home Health Care 1.85%; Nursing Home Facilities and Continuing Care Retirement Communities: 6.02%; Prescription Drugs: 12.12%; Durable Medical Equipment: 2.06%; Other Non-Durable Medical Products: 2.79%; Federal Administration Expenditures: 1.72%; State and Local Administration Expenditures: 0.66%; Net Cost of Health Insurance: 1.26%; Public Health Activity: 4.66%; Research: 1.45%; Structures and Equipment: 6.61% ~2017: Hospital care: 35.01%; Physician and Clinical Services: 12.47%; Other Professional Services: 2.27%; Dental Services: 2.55%; Other Health, Residential, and Personal Care: 6.69%; Home Health Care 1.88%; Nursing Home Facilities and Continuing Care Retirement Communities: 5.82%; Prescription Drugs: 11.89%; Durable Medical
Tennison et al.	2021	Health care's response to climate change: a carbon footprint assessment of the NHS in England	England	~1990: 33.8 Mt CO2eq ~1991: 33 Mt CO2eq ~1992: 33.2 Mt CO2eq ~1993: 30.8 Mt CO2eq ~1994:30.3 Mt CO2eq ~1995:30.4 Mt CO2eq ~1996: 29.4 Mt CO2eq ~1997 29.3 Mt CO2eq ~1998: 27.8 Mt CO2eq ~1999: 28.2 Mt CO2eq ~2000:27.5 Mt CO2eq ~2001: 26.8 Mt CO2eq ~2002: 26.1 Mt CO2eq ~2003: 27 Mt CO2eq ~2004: 27.1 Mt CO2eq ~2005: 27.6 Mt CO2eq ~2006: 27 Mt CO2eq ~2007: 28.3 Mt CO2eq ~2008: 28.7 Mt CO2eq ~2009: 28.4 Mt CO2eq ~2010: 28.1 Mt CO2eq ~2011: 27.3 Mt CO2eq ~2012: 27.9 Mt CO2eq ~2013: 28.3 Mt CO2eq ~2014: 28.3 Mt CO2eq ~2015: 27.3 Mt CO2eq ~2016: 26.4 Mt CO2eq ~2017: 25.7 Mt CO2eq ~2018: 25.4 Mt CO2eq ~2019 25 Mt CO2eq	~1990: 0.709 ~1991: 0.689 ~1992: 0.696 ~1993: 0.640 ~1994: 0.629 ~1995: 0.628 ~1996: 0.603 ~1997: 0.603 ~1998: 0.57 ~1999: 0.574 ~2000: 0.558 ~2001: 0.542 ~2002: 0.526 ~2003: 0.54 ~2004: 0.54 ~2005: 0.546 ~2006: 0.529 ~2007: 0.552 ~2008: 0.554 ~2009: 0.544 ~2010: 0.535 ~2011: 0.514 ~2012: 0.522 ~2013: 0.525 ~2014: 0.515 ~2015: 0.498 ~2016: 0.478 ~2017: 0.463 ~2018: 0.454 ~2019: 0.445	c.n.	~1990: Delivery of care: 47.93%; Supply Chain: 46.15%; Commissioned Healthcare: 0.56%; Travel: 5.62% ~1991: Delivery of care: 47.27%; Supply Chain: 46.06%; Commissioned Healthcare: 0.61%; Travel: 6.06% ~1992: Delivery of care: 45.81%; Supply Chain: 47.60%; Commissioned Healthcare: 0.60%; Travel: 5.99% ~1993: Delivery of care: 45.78%; Supply Chain: 46.75%; Commissioned Healthcare: 0.65%; Travel: 6.49% ~1994: Delivery of care: 46.20%; Supply Chain: 46.53%; Commissioned Healthcare: 0.66%; Travel: 6.93% ~1995: Delivery of care: 43.09%; Supply Chain: 49.01%; Commissioned Healthcare: 0.99%; Travel: 6.91% ~1996: Delivery of care: 44.03%; Supply Chain: 47.44%; Commissioned Healthcare: 1.02%; Travel: 7.17% ~1997: Delivery of care: 41.63%; Supply Chain: 50.51%; Commissioned Healthcare: 1.02%; Travel: 7.51% ~1998: Delivery of care: 44.96%; Supply Chain: 46.40%; Commissioned Healthcare: 1.08%; Travel: 7.91% ~1999: Delivery of care: 43.62%; Supply Chain: 47.16%; Commissioned Healthcare: 1.06%; Travel: 7.80% ~2000: Delivery of care: 41.45%; Supply Chain: 49.09%; Commissioned Healthcare: 1.09%; Travel: 8.36% ~2001: Delivery of care: 41.04%; Supply Chain: 49.25%; Commissioned Healthcare: 1.12%; Travel: 8.58% ~2002: Delivery of care: 40.61%; Supply Chain: 49.81%; Commissioned Healthcare: 1.15%; Travel: 8.43% ~2003: Delivery of care: 40.00%; Supply Chain: 49.63%; Commissioned Healthcare: 1.48%; Travel: 8.89% ~2004: Delivery of care: 37.27%; Supply Chain: 52.77%; Commissioned Healthcare: 1.48%; Travel: 8.49% ~2005: Delivery of care: 38.77%; Supply Chain: 50.72%; Commissioned Healthcare: 1.45%; Travel: 9.06% ~2006: Delivery of care: 38.15%; Supply Chain: 50.74%; Commissioned Healthcare: 1.48%; Travel: 9.63% ~2007: Delivery of care: 34.63%; Supply Chain: 54.42%; Commissioned Healthcare: 1.77%; Travel: 9.54% ~2008: Delivery of care: 33.10%; Supply Chain: 56.10%; Commissioned Healthcare: 1.74%; Travel: 9.06% ~2009: Delivery of care: 33.10%; Supply Chain: 56.69%; Commissioned Healthcare: 2.11%; Travel: 8.10% ~2010: Delivery of care: 30.96%; Supply Chain: 58.01%; Commissioned Healthcare: 2.49%; Travel: 8.90% ~2011: Delivery of care: 30.40%; Supply Chain: 57.14%; Commissioned Healthcare: 4.03%; Travel: 8.42% ~2012: Delivery of care: 31.54%; Supply Chain: 56.27%; Commissioned Healthcare: 3.94%; Travel: 8.24% ~2013: Delivery of care: 28.98%; Supply Chain: 57.95%; Commissioned Healthcare: 4.59%; Travel: 8.48% ~2014: Delivery of care: 27.86%; Supply Chain: 58.93%; Commissioned Healthcare: 4.29%; Travel: 8.57% ~2015: Delivery of care: 27.11%; Supply Chain: 60.44%; Commissioned Healthcare: 4.03%; Travel: 8.79% ~2016: Delivery of care: 26.52%; Supply Chain: 60.61%; Commissioned Healthcare: 3.79%; Travel: 9.09% ~2017: Delivery of care: 26.07%; Supply Chain: 61.09%; Commissioned Healthcare: 3.89%; Travel: 9.34% ~2018: Delivery of care: 25.20%; Supply Chain: 61.42%; Commissioned Healthcare: 3.94%; Travel: 9.45% ~2019: Delivery of care: 24.40%; Supply Chain: 62.40%; Commissioned Healthcare: 4.00%; Travel: 9.60%
Lenzen et al.	2020	The environmental footprint of health care: a global assessment	Global (189 countries)	~2000: Global: 1.70Gt CO2eq ~2001: Global: 1.70Gt CO2eq ~2002: Global: 1.76Gt CO2eq ~2003: Global: 1.87Gt CO2eq ~2004: Global: 1.87Gt CO2eq ~2005: Global: 1.92Gt CO2eq ~2006: Global: 1.98Gt CO2eq ~2007: Global: 2.04Gt CO2eq ~2008: Global: 2.04Gt CO2eq ~2009: Global: 1.98Gt CO2eq ~2010: Global: 2.10Gt CO2eq ~2011: Global: 2.14Gt CO2eq ~2012: Global: 2.19Gt CO2eq ~2013: Global:2.24Gt CO2eq ~2014: Global:2.29Gt CO2eq ~2015: Global:2.40Gt CO2eq; USA: 595.14Mt Co2eq; Japan: 190.52Mt Co2eq; Germany: 64.01Mt Co2eq; China: 375.50Mt Co2eq; France: 24.84Mt Co2eq; UK: 42.31Mt Co2eq; Russia: 219.64Mt Co2eq; Brazil: 103.28Mt Co2eq; Italy: 18.57Mt Co2eq; Canada: 43.09Mt Co2eq; Australia: 21.77Mt Co2eq; Spain: 31.32Mt Co2eq; Netherlands: 13.38Mt Co2eq; Norway: 4.23Mt Co2eq; Belgium: 7.22Mt Co2eq; Mexico: 16.55Mt Co2eq; Argentina: 16.38Mt Co2eq; Austria: 6.60Mt Co2eq; Israel: 6.65Mt Co2eq; Finland: 5.10Mt Co2eq; Poland: 13.20Mt Co2eq; South Korea: 24.88Mt Co2eq; Turkey: 11.95Mt Co2eq; Colombia: 5.08Mt Co2eq; Ireland: 3.91Mt Co2eq; Singapore: 8.60Mt Co2eq; Portugal 4.84Mt Co2eq; Thailand 13.36Mt Co2eq; Iran: 39.31Mt Co2eq; Indonesia: 14.29Mt Co2eq; Denmark: 3.37Mt Co2eq; South Africa: 15.93Mt Co2eq; Chile: 5.46Mt Co2eq; Greece: 4.00Mt Co2eq; New Zealand: 3.45Mt Co2eq; Czech Republic: 5.68Mt Co2eq; Taiwan: 10.49Mt Co2eq;	Norway: 0.81; Sweden: 0.58; Switzerland: 0.76; USA: 1.86; Finland: 0.93; Australia: 0.91; Netherlands: 0.79; Germany: 0.78; Belgium: 0.64; Japan: 1.49; Ireland: 0.83; Canada: 1.18; France: 0.37; Austria: 0.76; Israel: 0.82; Singapore: 1.55; Greenland: 76.99; UK 0.65; Denmark: 0.59; Italy: 0.31; New Zealand: 0.75; Spain: 0.67; Portugal: 0.46; Slovenia: 0.43; Curacao: 15.44; Russia: 1.53; Malta: 0.55; Uruguay: 0.79; Greece: 0.36; Czech Republic: 0.54; Slovakia: 1.27; Estonia 0.65; Hungary: 0.3; Chile: 0.31; Brazil: 0.5; Argentina: 0.38; Latvia: 0.36; Lithuania: 0.45; Poland: 0.35; South Korea: 0.49; Romania: 0.29; Colombia: 0.11; Mexico: 0.13; Taiwan: 0.45; Mauritius: 0.36; The former Yugoslav Republic of Macedonia: 0.36; Kazakhstan: 0.41; Turkey: 0.15; South Africa: 0.29; Thailand: 0.19; Malaysia: 0.25; China: 0.27; Georgia: 0.21; Iran: 0.50; Peru: 0.14; Ecuador: 0.09; Kuwait: 0.39; Ukraine: 0.27; Paraguay: 0.14; Venezuela: 0.15; Phillippines: 0.05; Kenya: 0.04; Uzbekuistan: 0.11; Indonesia: 0.06; India: 0.22; Viet Nam: 0.16	USA: 6.69%; Japan: 7.07%; Germany: 4.51%; China 3.1%; France: 3.19%; UK: 5%; Russia: 10.66%; Brazil: 3.11%; Italy: 2.31%; Canada: 4.76%; Australia: 3.25%; Spain: 5.39%; Netherlands: 4.02%; Sweden: 4.46%; India: 7.79%; Switzerland: 4.82%; Norway: 4.39%; Belgium: 3.45%; Mexico: 2.03%; Argentina: 3.88%; Austria: 4.54%; Israel: 4.99%; Finland: 4.26%; Poland: 3.01%; South Korea: 2.8%; Turkey: 1.71%; Colombia: 2.35%; Ireland: 3.98%; Singapore: 3.40%; Portugal: 4.83%; Thailand: 2.21%; Iran: 3.96%; Indonesia: 1.68%; Denmark: 3.78%; South Africa: 2.5%; Chile: 3.43%; Greece: 2.48%; New Zealand: 3.56%; Czech Republic: 3.08%; Taiwan: 1.81%; Phillippines: 2.74%; Romania: 3.52%; Malaysia: 2.04%; Hungary: 2.91%; Peru: 4.39%; Ukraine: 3.3%; Slovakia: 2.75%, Kazakhstan: 2.24%; Uruguay: 5.97%; Kenya: 2.71%; Viet Nam: 2.44%; Slovenia: 3.26%; Ecuador: 2.17%; Venezuela: 0.87%; Uzbekistan: 2.22%; Lithuania: 2.09%; Latvia: 3.72%; Estonia: 3.26%: Georgia: 4.13%; Paraguay: 1.68%; The former Yugoslav Republic off Macedonia: 4.12%; Kuwait: 1.45%; Malta: 3.41%; Mauritius: 3.36%; Caracao: 6.99%; Kyrgyzstan: 3.13%	-

Appendix: Method and transparency

Please use Ctrl + Scroll to zoom in this electronic appendix

Method	Demand Data source (detail)	Demand Data year	Number of demand/Expenditure categories	I-O table data source	I-O table data year	I-O model	Number of production sectors	Source of emission data/satelite account	Included Greenhouse Gases	Concardance matrix reported	Sensitivity/Uncertainty Analysis	Discussion of limitations
Top-Down	"National Medical Expenses Statistics"	2011	16	Ministry of internal Affairs and Communication	2011	SRIO (JIOT)	397	Japan National Report of GHGs Inventory (NRI)	CO2, CH4, N2O, HFCs, PFCs, SF6 and NF3	No	No	Yes
Top-Down	US National Health Expenditure Accounts	2003–2013	15	Federal Bureau of Economic Analysis	2002	SRIO	400+	EIOLCA	Equivalents	Yes	No	Yes
Top-Down	OECD: OECD health statistics database; China+India: World Bank health care expenditure	2014	OECD: 19	Eora	2014	MRIO (Eora)	14839	EDGAR	CO2	Available upon request	No	Yes
Top-Down	National Health Expenditures (NHEX) database maintained by the Canadian Institute for Health Information (CIHI)	2009-2015	13	(Statistics Canada)	2009	SRIO (Open IO-Canada)	112 sectors, 238 commodities	Statistics Canada Environmental Accounts and the Canadian National Pollutant Release Inventory	carbon dioxide, methane, and nitrous	Yes	No	Yes
Top-Down	Australian Institute of Health and Welfare (AIHW)	2015	16	Australian Bureau of Statistics	2014-2015	SRIO (Individually constructed)	360	Sydney University IELab	Equivalents	No	Monte-Carlo	Yes
Top-Down	national input–output table, China Health and Family Planning Statistics, China Construction Statistics, and China Science and Technology Statistics yearbooks	2013	8	National Bureau of Statistics of China	2012	SRIO	46	Climate Change Department of National Development and Reform Commission of the People's Republic of China. The People's Republic of China First Biennial Update Report on Climate Change	CO2, CH4, and N2O emissions	No	Monte-Carlo + Robustness (w/ onsite-emission in the medical institution sector) + Sensitivity (w/ energy intensities of floorspace of commercial buildings)	Yes
Hybrid	Scottish Government health expenditure	1990-2004	17	Scottish Government	1990-2004	SRIO (Scottish Government Input-Output tables)	123	UK National Statistics Environmental Accounts	CO2	Allocation without quantitative description	No	No
Hybrid	English Government	2004-2015	5	DEFRA	2004-2015	MRIO (UK-MRIO)	178	National Statistics Environmental Accounts	CO2 Beginning in 2010: CH4, N2O, HFCs, PFCs, SF6	Allocation without quantitative description	No	No
Top-Down	OECD health statistics database; World Health Organization, "Global Health Expenditure Database,"	2014	No	WIOD	2014	MRIO (WIOD)	2408	CO2: WIOD; Methane and Nitrous oxide: PRIMAP	carbon dioxide, methane and nitrous oxide gases	Reference to Pichler et al. (2019)	No	Yes
Top-Down	OECD Health Statistics 2017 supplied by the Austrian national statistical office	2014	9	Eora	2014	MRIO (Eora)	15909	EORA taken from EDGAR	CO2	Reference to Pichler et al. (2019)	No	Yes
Top-Down	Australian Institute of Health and Welfare	2016-2017	16	Australian Bureau of Statistics (ABS)	2017	SRIO (Individually constructed)	2880	No	No	No	No	Yes
Top-Down	National Health Expenditure Accounts of the Centers for Medicare and Medicaid Services (CMS)	2010-2018	16	Bureau of Economic Analysis	2012	SRIO (US Environmentally-Extended Input-Output model)	405	Inventory of U.S. Greenhouse Gas Emissions and Sinks	No	Yes	No	Yes
Hybrid	Public Expenditure Statistical Analysis Supply and Use tables from HM Treasury	1990-2019	19	DEFRA	1997-2016	MRIO (UK-MRIO)	424	UK MRIO	carbon dioxide [CO2], methane [CH4], nitrous oxide [N2O], and some categories of fluorinated gases/all Kyoto Protocol greenhouse gases	Yes	No	Yes
Top-Down	EORA	2000-2015	163	Eora	2000-2015	MRIO (Eora)	14838	EORA taken from EDGAR	carbon dioxide [CO2], methane, nitrous oxide, hydrofluorocarbon, chlorofluorocarb	No	Uncertainty	Yes

Appendix: Transparency Score

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Author	Year	Author (Year)	Title	Health Care System	Total Carbon Footprint	tCO2/capi-ta	% of total emission	Breakdown	Method	Demand Data source	Demand Data year	Number of demand/ Expend-iture cate-gories	I-O table data source	I-O table data year	Multiregionality of the model	Number of productio n sectors	Source of emission data/ satelite account	Included Green-house Gases	Concardance matrix reported	Sensitivity /Un-certainty Analysis	Dis-cussion of limitations		
Nansai et al.	2020	Nansai et al. (2020)	Carbon footprint of Japanese health care services from 2011 to 2015	Japan	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	14	82,35%
Eckelman et al.	2016	Eckelman et al. (2016)	Environmental Impacts of the U.S. Health Care System and Effects on Public Health	USA	1	0	1	1	1	1	1	1	1	1	1	1	1	0,5	1	0	1	14,5	85,29%
Pichler et al.	2019	Pichler et al. (2019)	International comparison of health care carbon footprints	OECD countries; China; India	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	16	94,12%
Eckelman et al.	2018	Eckelman et al. (2018)	Life cycle environmental emissions and health damages from the Canadian healthcare system: An economic-environmental-epidemiological analysis	Canada	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	16	94,12%
Malik et al.	2018	Malik et al. (2018)	The carbon footprint of Australian health care	Australia	1	0	1	1	1	1	1	1	1	1	1	1	1	0,5	0	1	1	14,5	85,29%
Wu	2019	Wu (2019)	The carbon footprint of the Chinese health-care system: an environmentally extended input-output and structural path analysis study	China	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	16	94,12%
NHSScotland	2008	NHSScotland (2008)	National Health Service Scotland Carbon Footprint of NHS Scotland(1990-2004)	Scotland	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	13	76,47%
SDU series	2016	SDU series (2016)	Carbon update for the health and care sector in England 2015	NHS England	1	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	12	70,59%
HCH	2019	HCH (2019)	Health Care´s Climate Footprint	43 countries	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	15	88,24%

Weisz et al.	2020	Weisz et al. (2020)	Carbon emission trends and sustainability options in Austrian health care	Austria	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	16	94,12%
Malik et al.	2021	Malik et al. (2021)	Environmental impacts of Australia's largest health system	New South Wales, Australia	1	0	1	0	1	1	1	1	1	1	1	1	0	0	1	0	1	12	70,59%
Eckelman et al.	2020	Eckelman et al. (2020)	Health Care Pollution And Public Health Damage In The United States: An Update	USA	1	0	0	1	1	1	1	1	1	1	1	1	1	0	1	0	1	13	76,47%
Tennison et al.	2021	Tennison et al. (2021)	Health care's response to climate change: a carbon footprint assessment of the NHS in England	England	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	15	88,24%
Lenzen et al.	2020	Lenzen et al. (2020)	The environmental footprint of health care: a global assessment	189 countries	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	15	88,24%
					14	7	11	12	14	14	14	13	14	14	14	14	13	11	8	3	12		
					100,00%	50,00%	78,57%	85,71%	100,00%	100,00%	100,00%	92,86%	100,00%	100,00%	100,00%	100,00%	92,86%	78,57%	57,14%	21,43%	85,71%		

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Carbon footprint of healthcare systems: A systematic review of evidence and methods

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ABSTRACT

Objective: Given the demand for net-zero healthcare, the carbon footprint (CF) of healthcare systems has attracted increasing interest in research in recent years. This systematic review investigates the results and methodological transparency of CF calculations of healthcare systems. The methodological emphasis lies specifically on Input-Output based calculations.

Design**:** Systematic Review according to the PRISMA guideline.

Data sources: PubMed, Web of Science, EconBiz, Scopus, and Google Scholar were initally searched on November 25, 2019. Search updates in Pubmed and Web of Science were considered until December 2023. The search was complemented by reference tracking within all the included studies.

Eligibility Criteria: We included original studies that calculated and reported the CF of one or more healthcare systems. Studies were excluded if the specific systems were not named or no information on the calculation method was provided.

Data extraction and synthesis: Within the initial search, two independent reviewers searched, screened, and extracted information from the included studies. A checklist was developed to extract information on results and methodology and assess the included studies' transparency.

Results: 15 studies were included. The mean ratio of healthcare system emissions to total national emissions was 4.9% [minimum 1.5%; maximum 9.8%], and CFs were growing in most countries. Hospital care led to the largest relative share of the total CF. At least 71% of the methodological items were reported by each study.

Conclusions: The results of this review show that healthcare systems contribute substantially to national carbon emissions, and hospitals are one of the main contributors in this regard. They also show that mitigation measures can help reduce emissions over time. The checklist developed here can serve as a reference point to help make methodological decisions in future research reports as well as report homogeneous results.

Keywords: life-cycle assessment, input-output, global warming potential, healthcare

STRENGTHS AND LIMITATIONS OF THE STUDY

- The assessment of methodological choices and the transparency of methods when assessing the greenhouse gas emissions of entire sectors in systematic reviews can help deepen our understanding of the results.
- The systematic review of all available evidence on greenhouse gas emissions of and within healthcare can help to understand its impact and to identify reduction potentials.
- This review was limited to articles in English and German, and excluded assessments, grey literature from public reports, and reports from statistical offices published in other languages.

INTRODUCTION

Background

Climate change is one of the most pressing issues of our time[1]. Considering the correlation between the gross domestic product (GDP) and carbon emissions[2], the healthcare industry is likely an essential contributor to greenhouse gas (GHG) emissions. Demographic shifts and income effects have likely spurred greater demand for healthcare services, a trend projected to persist and further elevate the economic significance of the healthcare industry[3]. Evidence on healthcare's GHG emissions is needed to understand its role better.

Methods for calculating a carbon footprint (CF) can be broadly categorized into bottom-up and top-down approaches. Bottom-up methods, such as process-based lifecycle assessments (LCA), require extensive data, which currently limits their application at a sectoral level. However, the CF of various sectors can be estimated using a more uncertain top-down-methodology, providing a trade-off for broader coverage. In this case, emissions are divided according to the final demand or economic sectors of emission occurrence.

Input–output (I–O) analysis, which follows this approach, can be used to estimate sectoral CF[4]. Calculations of the CF use the static open-quantity I–O model in combination with an environmental extension. They rely on two fundamental building blocks: an I–O table and a demand vector. The I–O table describes the interactions between the sectors of production, often in monetary terms, and are usually constructed by national statistics offices. With additional information on their environmental impact, the emission intensity of a sector and its upstream production processes can be calculated. The demand vector represents the expenditures of the relevant sectors. For example, the demand vector of the healthcare sector includes expenditure on diesel fuel to power ambulances, electricity consumed by hospitals, and all other forms of energy. It may be necessary to synchronize the structures of the I–O table and the demand vector by balancing the definitions of different sectors and adjusting the level of sectoral aggregation.

I–O models can be grouped into single-region I–O (SRIO) and multi-region I–O (MRIO) models. SRIO models utilize I-O data from a single country, thus restricting their scope to domestic production and emissions only. MRIO models connect multiple I–O tables from multiple countries, and can thus account for different levels of production and "trade" in emissions (i.e., emissions occurring in one country related to the final demand of another country). The need for synchronized data from multiple countries complicates the development and update of the data of MRIO models.

The results of CF calculations for a specific sector can be influenced by methodological choices, including the selection between SRIO or MRIO models and the GHGs taken into account. Therefore, comprehensive reporting is needed to ensure the transparency of methodological choices, the data, and the results. However, our search of the literature yielded neither a standardized procedure nor standardized reporting.

Objective

The aim of this study is to conduct a systematic review of research utilizing I-O analysis to quantify the CF of systems, encompassing total CF, CF per capita, and its proportion relative to the national CF. Furthermore, data on emission trends over time, can deepen the understanding of the trajectory of the CF of healthcare systems. Finally, an assessment of the methodological choices and their transparency within the reviewed studies can help to discuss the state of the methodology and provides a foundation to discuss methodological differences between the studies.

METHODS

Search strategy and selection criteria

This systematic review was performed by following the PRISMA guidelines[5] (the checklist is provided in the Appendix). The databases PubMed, Web of Science, EconBiz, Scopus, and Google Scholar were searched for studies on November 25, 2019. The search was complemented by reference tracking within all the included studies. The updated search considered hits in Pubmed and Web of Science up to December 2023.

Following the screening of the titles and abstracts, studies were included for further investigation if they had (i) addressed the method of CF calculation (ii) addressed one or more healthcare systems or subsystems, and (iii) been written in English or German. A healthcare system was defined as the national healthcare system, federal system, and/or state system. Single entities, such as individual hospitals, and specialized branches, such as dentistry, were excluded. In addition to the criteria used for screening the titles and abstracts of articles, full-text articles were excluded if they (i) did not name the specific healthcare (sub)system, (ii) did not calculate the CF, or (iii) did not provide any information on the method of calculation used. In the initial search, two of the authors separately screened titles and abstracts, read the full text, extracted data and assessed the transparency. In the case of disagreement, decisions were made through discussion until a consensus was reached. During the search update these steps were conducted by one person.

Data extraction and analysis

The CF per capita, the contribution of healthcare to the country's total CF emissions, and the origins of emissions were used as main results of the studies. The breakdown of the emission sources could be in scopes, demand categories, or places of origin. The Greenhouse Gas Protocol Corporate Accounting and Reporting Standard[6] proposes three standardized scopes. Scope 1 represents direct emissions from owned or controlled sources, Scope 2 represents indirect emissions generated by the purchased energy, and Scope 3 represents all indirect emissions that occur in the value chain. The categories of demand included the classes of expenditures of the demand vector, and the places of the origin of emissions were divided into hospitals, ambulatory services, and so on.

In addition to evaluating their general characteristics and results, we developed and applied a checklist to assess the methodological transparency of the studies under consideration. We opted to use the term 'transparency' rather than 'quality' to address the issue that even a flawless study could receive a low score if the authors failed to adequately report their methodology. The checklist served as both a qualitative extraction tool and a quantitative transparency tool. The qualitative extraction tool facilitated the assessment of information from each included study, with responses to each criterion collected accordingly. As a quantitative transparency tool, it was evaluated whether the criteria were adequately addressed. When information was provided, the criterion was considered fulfilled, resulting in an increase in the transparency score. All criteria were weighted equally, therefore for each "fulfilled" criterion one point was added to the transparency score, with a maximum of 17 points per study.

The utilization of I-O data can introduce uncertainties into the assessment, given that the top-down approach relies on aggregated information from industrial sectors. When heterogeneous products with varying emission intensities are grouped into one industry, aggregation errors might occur: the average emission intensity of the aggregated industry would not appropriately reflect the emissions caused by the specific product within the industry[7]. Therefore, information on the extend of usage of I-O method (criterion 5), and the number of industry sectors (criterion 12) could help to understand the scope of this uncertainty.

The choice between MRIO and SRIO (criterion 11) can also help to understand the level of uncertainty. While MRIOs can account for differences between countries and trade between these countries, SRIO might provide a more detailed framework of the domestic economy. Finally, the specific source of the I-O tables (criterion 9) and emission data (criterion 13) can help the reader to assess the quality of the used data.

Similar to the I-O data, the level of aggregation within the demand data can impact the accuracy of the results. The number of demand or expenditure categories (criterion 8) can indicate on the level of aggregation and the source of demand data (criterion 6) could help to assess the quality of the data source. The quality of the outcomes is also influenced by the alignment between the temporal representativeness of the demand data (criterion 7) and the I-O data (criterion 10). Changes over time (e.g. in technology, import and exports) can impact the results and in the best case both data sources refer to the same year. Finally, information on the matching process of demand categories and industry sectors, the publication of the concordance matrix (criterion 15), increases transparency for the reader.

The quantitative (criterion 16) and qualitative (criterion 17) assessment of uncertainty helps the readers to contextualize the results. A list of the included GHGs can indicate the scope of the study, in this case 0.5 were given, when the unit (typically CO_2equivalents (CO_2eq)) was mentioned and another 0.5 points if all included GHGs were listed. For the final transparency checklist, the criteria on outcomes (table 1a) and on methodology (table 1b) were combined.

Table 1a: Extracted outcomes

	Number	Criterion
System description and outcomes	0 *	System description
	1	Total carbon footprint
	2	Carbon footprint as a share of the total national CF
	3	CF per capita

** not included in the transparency score*

Table 1b: Extracted methodological items

Method	5	LCA method
	6	Source of demand data (detail)
	7	Year of demand data
	8	Number of categories of demand or expenditure
	9	Data source of I–O table
	10	Year of I–O table
	11	Multi-regionality of the model
	12	Number of production sectors
	13	Source of emission data
	14	GHGs considered
	15	Concordance matrix reported
	16	Sensitivity and uncertainty analysis
	17	Discussion of limitations

Emissions over time

To assess trends in GHG emissions of healthcare, data from all studies that reported total emissions for more than one year were taken. The data were normalized to the respective starting point of the report as a base year. Therefore, GHG emissions of time period t were divided by the GHG emissions of the base year t_0 and used in a descriptive analysis.

Patient and public involvement

None

RESULTS

A total of 4,285 records were identified in the three searches (figure 1). After removing duplicates and searching for eligible title, abstracts, and full texts, 15 reports were included in this review (figure 1). A summary of included studies is provided in Table 2. The detailed results of the data collection are listed in the appendix.

-Insert figure 1 around here-

Characteristics of the studies considered

Eleven studies focused on a single national healthcare system, including England [8 9], Japan [10], USA [11 12], Canada [13], Scotland [14], China [15], Australia [16], Austria [17], and the Netherlands[18]. The series of CFs from the Sustainable Development Unit of the English NHS was aggregated, and only the newest available report was cited. One study examined the healthcare system of the largest Australian state, New South Wales [19], while three studies reported on healthcare systems in multiple countries. Pichler et al. [20] reported results for 36 countries, Healthcare without Harm (HCH) for 43 countries [21], and the investigation by Lenzen et al. [22] considered 189 countries.

Excluding the one that assessed the Scottish NHS, all studies were published after 2016. However, it's worth noting that the year of the analysis could be older. For instance, the study by Nansai et al. [10] was published in 2020 but utilized demand data from 2011.

Table 2: Characteristics and main results of the studies considered in this review; CF: carbon footprint, Mt: megatonnes CO2eq: CO2 equivalents, t: tonnes, cap: capita

Author (Year)	Healthcare system	Data year	CF in Mt CO_2eq	% of total national CF	tCO2eq/cap	Transparency score
Tennison et al. [8]	England	2018	25	n.i.	0,445	88%
SDU [9]	England	2019	25	n.i.	n.i.	71%
Nansai et al. [10]	Japan	2011	72	4,6	0,49	82%
Eckelman and Sherman [11]	USA	2013	655	9,8	2,07	85%
Eckelman et al. [12]	USA	2018	554	n.i.	n.i.	76%
Eckelman et al. [13]	Canada	2015	33	5,7	0,92	94%

Health Facilities Scotland [14]	Scotland	2004	2,6	3,6	0,52	76%
Wu [15]	China	2012	315	2,7	0,23	94%
Malik et al. [16]	Australia	2015	36	7,0	1,50	85%
Weisz et al. [17]	Austria	2014	6,8	7	0,8	94%
Steenmeijer et al. [18]	Netherlands	2016	17,575	17,6	n.i.	88%
Malik et al. [19]	New South Wales, Australia	2017	0,008	6,6	n.i.	71%
Pichler et al. [20]	OECD countries; China, India	2014	s. Appendix	Ø 5,5 s. Appendix	s. Appendix	94%
	43 countries; EU; rest of the world	2014	s. Appendix	Ø 4,4s. Appendix	s. Appendix	88%
Lenzen et al. [22]	Global	2015	2 290	n.i.	n.i.	88%
* n.i.= not identified						

Differences in methodology and data

Eleven studies considered top-down data on emissions, while three studies employed bottom-up data on energy usage [8 9 14]. Steenmeijer et al. [18] incorporated bottom-up data regarding the quantities of anesthetic gases, inhalers and travel.

Most single-country studies used SRIO data from the respective governmental offices. In contrast, the studies on British and Dutch healthcare, and those that considered more than one country, used MRIO data. Additionally, Malik et al. [23] used MRIO data, however, the database only included data from Australian regions. The EORA database emerged as the most frequently utilized MRIO database (three times), with one study each employing the WIOD database, the EXIOBASE database, and the MRIO database provided by the British Department for the Environment, Food, & Rural Affairs.

The number of production sectors varied among the SRIO studies, ranging from 46 to 405 sectors. The MRIO studies typically utilized more extensive databases comprising approximately 15,000 sectors, although the MRIO study focusing on the UK considered 424 sectors.

All studies considered CO_2 emissions. However, only five studies considered the six GHGs covered in the Kyoto Protocol; three studies considered CO2, methane, and nitrous oxide; two reported only that they had used CO2eq as unit; and two studies did not report any included GHG or the unit in which the outcomes were reported. The data on emissions were drawn mostly from national accounts in the case of SRIO databases and integrated accounts in the case of MRIO databases. One study did not report the source of its emission account data.

The demand data was taken either from official health expenditure accounts or from international organizations such as the WHO and the World Bank (which uses data provided by national offices and accounts). Lenzen et al. [22] identified and directly used data on healthcare-related sectors from the MRIO database EORA. The number of reported expenditure accounts varied, mostly ranging from 13 to 19, although three studies reported fewer accounts. Weisz et al. [17] utilized nine accounts, Wu [15] used eight accounts, and the study on the NHS in England employed five accounts [9]. Due to the distinct methodologies employed by Lenzen et al. [22] and the structure of the EORA database, which reports country-specific sectors, they utilized 163 sectors from the EORA as demand data.

The time periods covered by the demand data were largely consistent with those covered by the respective I-O data. Some studies reporting outcomes for more than one year only used one reference year for the I-O database and adjusted the demand data for inflation. [11-13]. The lag between the time at which the data were collected and the time of publication of the corresponding study ranged from three to six years, with deviations in the studies by Nansai et al. [10] Eckelman et al. [12] (two years) and in the report by the SDU [9]. The latter reported the CF periodically; the lag between the latest publication and the latest data was one year [9]. Further information on this is provided in the appendix.

Five studies provided their concordance matrices, which link the categories of demand with the industrial sectors. The authors of one study had made their matrix available upon request, and two articles had referred to a matrix previously used in another study. Five studies did not report their concordance matrices.

Reporting of the results

The origins of emissions were documented six times in the three scopes defined by the GHG protocol. Emission sources were reported eight times in the (sub)categories of final demand, such as hospitals or pharmaceuticals. Two studies reported the economic sector in which the emissions occurred, e.g., the textile sector or the manufacture of fuels. Furthermore, three studies reported a breakdown of emissions by employing more than one reporting structure. Several differences were observed in the scopes of the reported results. Some studies directly referenced the GHG protocol while others reported emissions in divisions, such as travel, energy, procurement, etc. 47% of the articles did not normalize the results by reporting the CF per capita.

Overall transparency

Except for the three criteria “reporting of the concordance matrix”, “uncertainty analysis”, and “CF per capita”, all criteria were fulfilled by at least 75% of the studies (Figure 2). The studies fulfilled between 70.5% and 94% of all criteria with a mean of 85% (Figure 3).

-Insert figure 2 around here-

-Insert figure 3 around here-

OUTCOMES

Emissions over time

The results of the time series revealed successful efforts to mitigate the CF by the NHS in England and Scotland (Figure 4). In the nearly three decades from 1990 to 2019, the English NHS reduced its CF by roughly 25%. The four remaining countries (Japan, Canada, USA, and Australia) examined in the studies considered here and the global trend showed increased CF due to healthcare (Figure 4). The annual increase in the CF ranged from 0.7% (USA, 2010–2018) to 3.8% (Japan, 2011–2015) over the observed period, with the CFs of Canada (1.9%, 2009–2015), USA (2.8%, 2011–2015), and Australia (2.9%. 2013–2015) in between these extremes. The global trend showed an increase in the CF of 2.7% per year from 2000 to 2015.

-Insert figure 4 around here-

Breakdown

The emission sources were mainly reported using the scope system from the GHG protocol or the categories of expenditure, i.e., the categories of final demand. The largest dataset that used the categories of final demand was provided by Pichler et al. [20], who applied this to 36 countries and reported the average values. Medical retail (i.e., provider of healthcare products without medical services, e.g., pharmacies), hospitals, and ambulatory healthcare services constituted 80% of the CF of healthcare, with medical retail contributing 33.1%, hospitals 28.6%, and ambulatory healthcare services 18%. They also made a major contribution to the CF in Japan (hospitals, 25.1%; ambulatory services, 22.7%) , USA in 2013 (hospital care, 36%; physician and clinical services, 12%) [11] and in 2018 (hospital care, 34.9%; physician and clinical services, 12.6%; ambulatory medical services, 4.8%) [13], Australia (public hospitals, 34.4%; private hospitals, 10.2%; ambulatory medical services, 15%) [16], China (public hospitals, 47%; private hospitals, 4%) [15], and Austria (hospitals, 32%; ambulatory services, 18%) [17]. Other important categories of emissions were construction and pharmaceutical products, at around 10% [11 16 20], with a higher share in China (pharmaceuticals, 18%; construction, 15%) [15].

An alternative approach involved categorizing emissions into direct emissions, indirect emissions through electricity production, and other indirect emissions. This division along these lines could also align with the three GHG protocol scopes.

By averaging data from 43 countries, HCWH reported a distribution of 17% for scope 1 emissions, 12% for scope 2 emissions, and 71% for scope 3 emissions [21]. These findings, particularly the significance of scope 3 emissions, are corroborated by evidence from single-country studies. [8 11 12 14 24]. The scope 3 emissions were further divided into those due to travel (patient and visitor travel, and staff commutes), production of pharmaceuticals, and medical instruments and equipment, which accounted for the largest share of scope 3 emissions.

Scotland's scope 3 travel emissions in 2004 were 18% while those of England accounted for 13% in 2015 and 9.6% in 2018 [9]. The share of emissions owing to pharmaceutical production ranged from 11% and 18%, and that owing to medical instruments and equipment accounted for 7%–10% of the total CF [13 14 24].

The ratio of emissions by the healthcare sector to the total CF in studies focused on a single country ranged from 2.7% in China in 2012 [15] to 9.8% in the USA in 2013 [11]. The three cross-national studies considered here estimated that healthcare had contributed 5.5% [20] on average to the national CF in 2014 and 4.4% in 2015 [22].

DISCUSSION

Interpretation of results

The results indicate that healthcare significantly contributes to the CF, both in absolute numbers and in relation to a country's overall emissions and its per capita emissions. However, the results varied among the studies, and their calculation methods were heterogeneous and frequently not fully transparent. The breakdown of the sources of emissions revealed the major contribution made by hospitals.

The time series results showed that the trend of emissions due to healthcare was positive in all the countries considered, i.e., they were increasing, except in Scotland and England. These results align with the graphical results provided by Lenzen et al. [22]. Furthermore, they indicated that the efforts of the British NHS systems to reduce their carbon footprint based on the Greener NHS program was effective in reducing GHG emissions. The breakdown of the sources of emissions verified the important contribution of hospitals. However, hospitals provide the majority of medical care in many countries. Therefore, their large CF is not surprising but might motivate the relevant decision-makers to allocate scarce resources more efficiently. The breakdown further showed that a large portion of the CF of healthcare stemmed from scope 3 emissions. Decision-makers may conclude that the most considerable reduction in emissions can be obtained by considering staff and patient travel. Therefore, "greening" the healthcare sector requires a sustainable transportation system and green healthcare goods.

Most data were from the OECD countries, China, and India. The only exception was the work by Lenzen et al. [22], who considered 189 countries in their analysis [22]. However, even if the distribution of countries limits the representativeness of the results, the findings are consistent with the fact that OECD countries are the main emitters of GHGs.

While heterogeneity in methodology, in general, can lead to more robust results and a more informative perspective on the issue at hand, the differences in I–O methodologies to calculate the CF of healthcare may reduce the comparability of the results. However, the choice of method depends on the corresponding research question, for example, while SRIO may be more up to date and include a more detailed description of the domestic production sectors, MRIO can account for international trade and differences in production emissions between countries.

Limitations

This review has several limitations. First, the review process used here was limited due to restrictions on the language used in the study and those related to access. Second, it is possible that further CF assessments exist which were published in the official languages of many countries in the grey literature, such as publications by national statistics offices or governmental agencies. Because this review included only publications in English and German, many such studies have likely been neglected. Third, the reporting scheme and transparency score used in this study may have limitations. Both were based only on a consensus among the authors. The instruments used to assess the quality of the published studies are typically chosen based on a broad consensus among experts, such as in the case of the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) [25]. However, we did not find similar guidance for I–O analyses. Finally, the review is limited as the studies only report averages instead of confidence intervals (CI) or data ranges. Only Malik et al. [16] report the 68% CI with a range of 20,748 kt CO2eq in the results (68% CI 25,398kt CO2eq –46,146 kt CO2eq). Therefore, the results presented in both the individual studies and in this review should not be regarded as precise measurements, but rather as indicative trends or directions.

Implications for further research

This review identified research gaps that should be investigated by future research. First, there is a need to assess the potential effects of efforts to reduce emissions on the system and pathways to a low-carbon healthcare system. Second, it should be examined errors of aggregation when using the I–O methodology in the healthcare context. Third, the differences in the outcomes when making different methodological choices (SRIO or MRIO, systemic boundaries, etc.) should be analyzed to guide future research.

The transparency checklist used in this study can serve as an initial reference point for future developments. For example, in the checklist's current state, all criteria are weighted equally. However, some might be less crucial to delivering harmonized study findings. An extended consensus process with further experts is proposed to validate the checklist further and increase its value for research and practice.

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DECLARATIONS

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Mattis Keil: Methodology, Screening, Formal Analysis, Writing – Original Draft, Writing-Review and Editing, Visualization; **Leonie Frehse:** Methodology, Screening, Formal Analysis, Writing – Original Draft; **Marco Hagemeister:** Methodology, Screening, Formal Analysis, Writing – Original Draft **Mona Knieß:** Methodology, Screening, Formal Analysis, Writing – Original Draft **Oliver Lange:** Conceptualization, Methodology, Writing - Review and Editing**, Tobias Kronenberg:** Methodology, Writing – Review and Editing **Wolf Rogowski:** Conceptualizing, Methodology, Writing - Review and Editing, Supervision, Project administration. All authors have read and approved the final manuscript for publication.

Conflict of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data statement

The data that support the findings of this study are available in Appendix 4a "System description and results" and Appendix 4b "Methods and transparency." Further data are available from the corresponding author, [MK], upon reasonable request.

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Figure legends/captions

Figure 1: Prisma Flow Diagram, based on Page et al. (2021)

Figure 2: Fulfilment rate of the transparency and reporting criteria

Figure 3: Transparency score in % per article

Figure 4: Emission trends over time

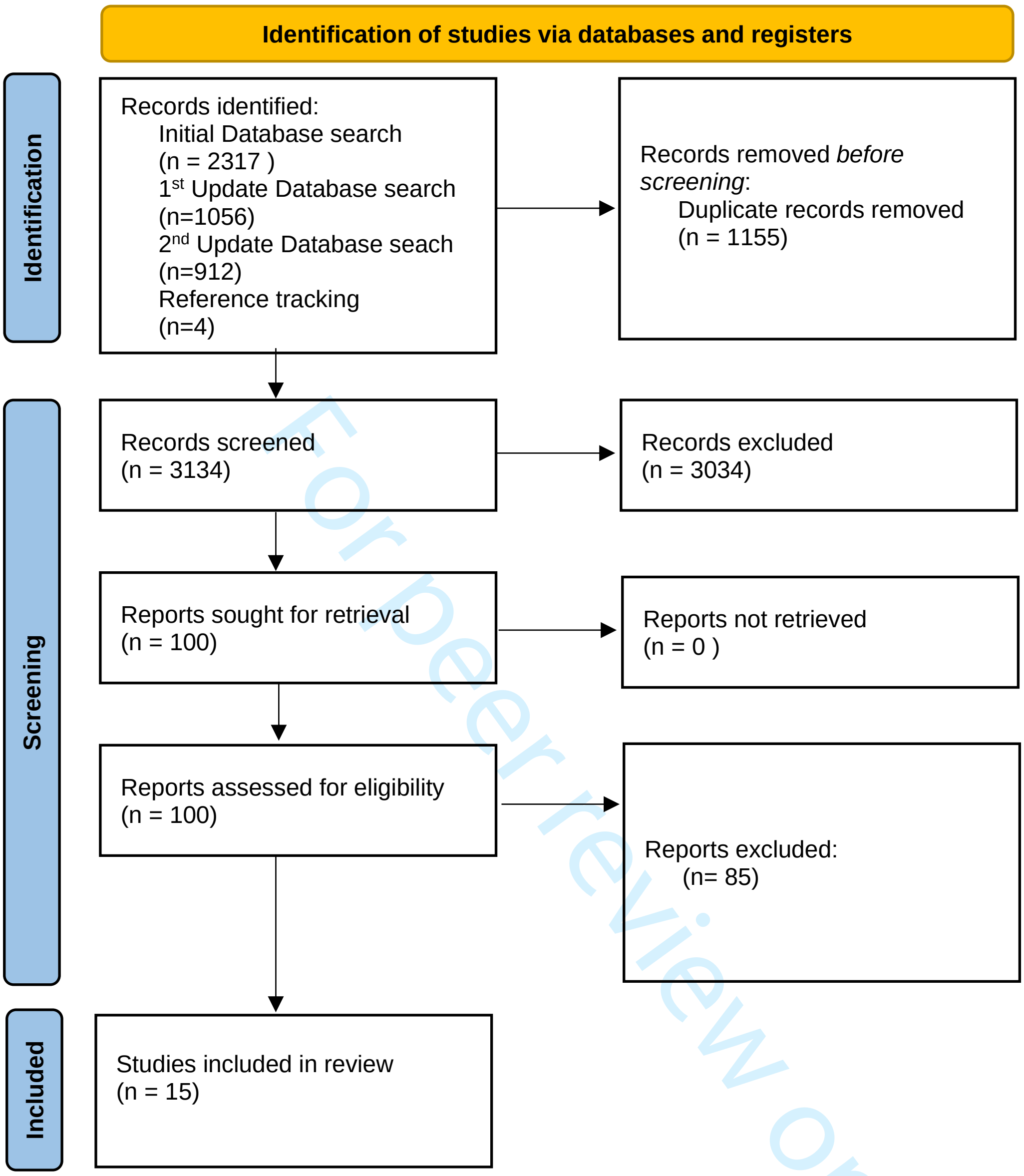

Figure 1: Prisma Flow Diagram, based on Page et al. (2021)

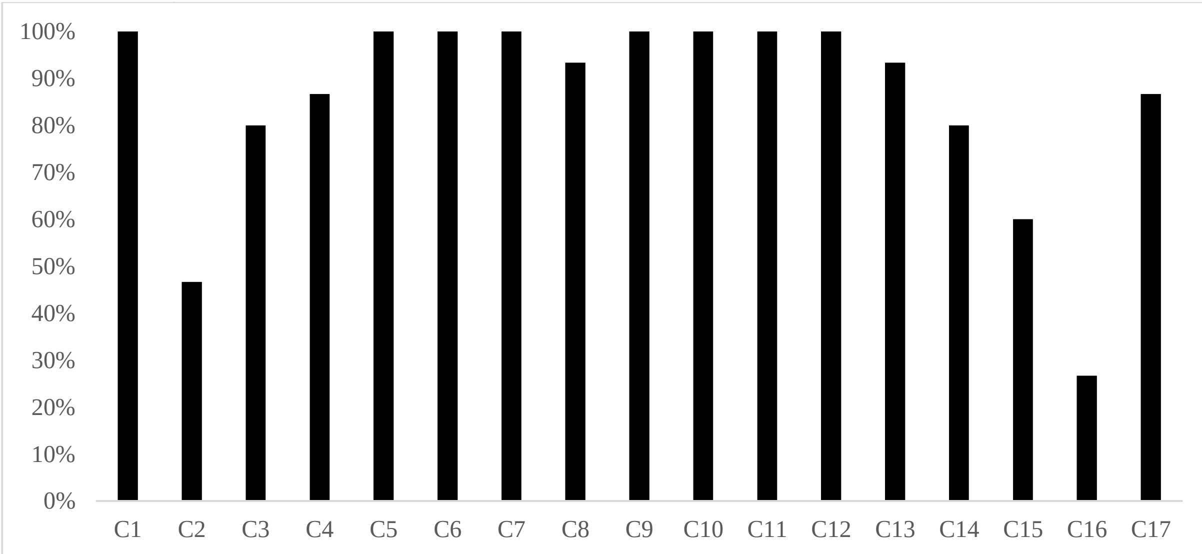

Figure 2: Fulfilment rate of the transparency and reporting criteria

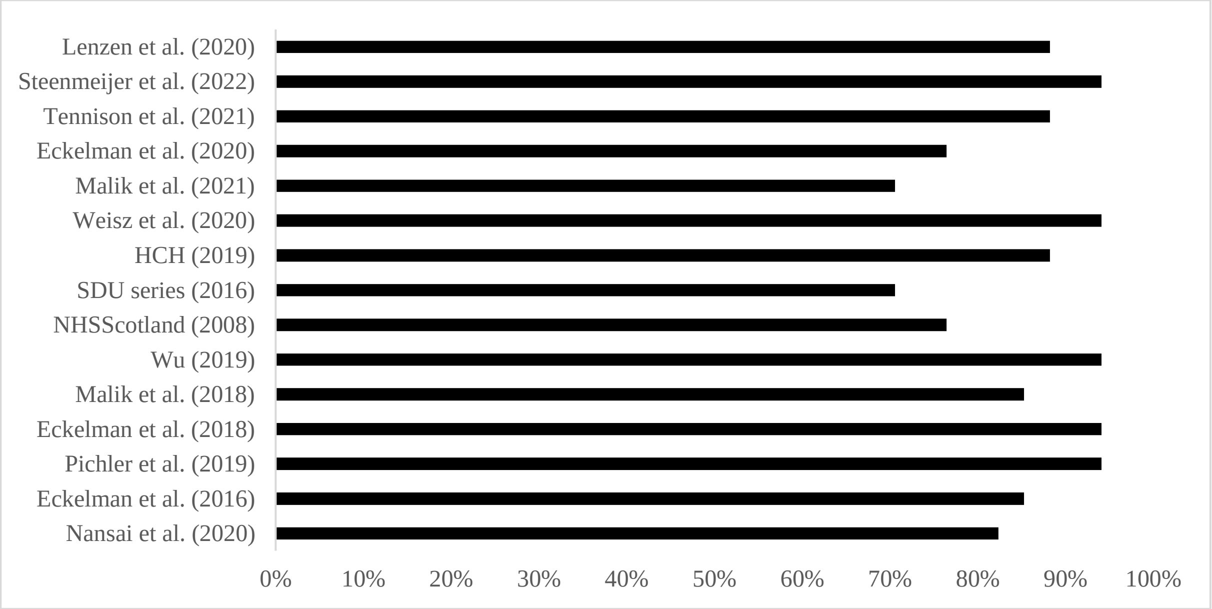

Figure 3: Transparency score in % per article

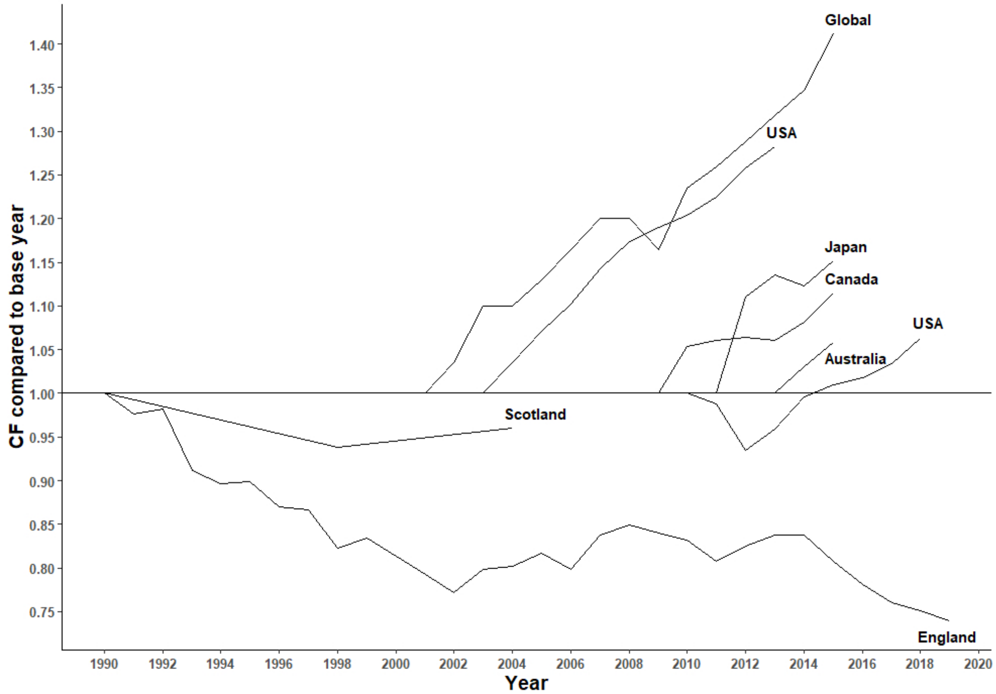

Figure 4: Emission trends over time

83x59mm (300 x 300 DPI)

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Title, Methods
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page 1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Introduction on Page 3
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Introduction on Page 3
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Methods section on Page 4
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Methods section on Pages 3-4
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Supplementary materials
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Methods section on Page 4
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Methods section on Page 4
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Methods section on Pages 4-5
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Methods section on Pages 4-5
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	n.a.
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Methods section on Page 4
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	n.a.
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	n.a.

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	n.a
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	n.a.
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	n.a.
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	n.a
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	n.a.
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	n.a
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Results on page 5
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	n.a.
Study characteristics	17	Cite each included study and present its characteristics.	Results on pages 5-6
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	n.a.
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Results on pages 6-7
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	n.a.
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	n.a.
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	n.a.
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	n.a.
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	n.a.
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	n.a.
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Discussion on page 8
	23b	Discuss any limitations of the evidence included in the review.	Discussion on page 8
	23c	Discuss any limitations of the review processes used.	Discussion on page 8
	23d	Discuss implications of the results for practice, policy, and future research.	Discussion on page 9
OTHER INFORMATION			

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Page 9
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Page 9
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	n.a.
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Page 10
Competing interests	26	Declare any competing interests of review authors.	Page 10
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Appendix

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

For more information, visit: http://www.prisma-statement.org/

S1: Further description of the transparency criteria

#	Criteria	Further description
System description and results		
0 (not included in the transparency score)	System description	It should be reported which national healthcare system was assessed. Healthcare system was defined, closely to the definition of the WHO as follows: *"A health system consists of organizations, people and actions whose primary intent is to promote, restore or maintain health."*
1	Total Carbon Footprint	The total CF of a healthcare system can help to understand the total impact the system has on climate change
2	Carbon Footprint as a share of the total national CF	The share of healthcare's CF of the total national CF can help to understand the importance of the healthcare system to mitigate the climate impact of a country as well as to analyze systematic differences in the importance of the healthcare systems in mitigating the national CF between countries
3	CF per capita	The CF per capita can help to compare healthcare systems between different-sized countries.
4	CF breakdown	The division of total CFs in scopes or subcategories can help to understand the "hot spots" in GHG emissions within healthcare systems.
Method and Transparency		
5	LCA method	The LCA method can be distinguished between Top-Down (i.e. Using only Input-Output Data), Bottom-Up (i.e. using only Process-based data), and Hybrid (Using both data types). Each type has its advantages and disadvantages and should be reported to enable a first assessment of the used method.
6	Demand Date source (detail)	To avoid inaccurate, outdated, or unfitting data the data source is important to report for transparency.
7	Demand Data year	To avoid inaccurate, outdated, or unfitting data the data year is important to report for transparency.
8	Number of demand or expenditure categories	The number of demand or expenditure categories can help to assess the level of detail in which the healthcare system is modeled. The more expenditure categories are used, the higher the level of detail might be.
9	I-O table data source	Similar to the demand vector, the data source of the I-O table is important to ensure the data quality and transparency
10	I-O table year	Similar to the demand vector the data year of the I-O table is of importance to ensure the data quality and transparency
11	Multiregionality of the model	I-O tables can be distinguished in SRIO, which aggregates the economic sectors of a single country, or MRIO, which aggregates the sectors of multiple countries. As each of the models has its implications it is important to report the model type.
12	Number of production sectors	The number of production sectors within the I-O model can help to estimate the level of aggregation. The more production sectors are used the less aggregated the model might be.

13	Source of emission data	The report of emissions data sources ensures the quality.
14	Included GHGs	The results might vary dependent on the included GHGs with more included GHG leading to a higher CF. This leaves room for biases and reduced comparability between the studies. A list of the included GHGs and the used unit for the results can help to identify differences between the studies and contextualizes the results.
15	Concordance matrix reported	The bridge matrix connects the demand vector with the IO table. Each value in the demand vector, representing a demand from a certain economic sector, has to be connected to one or multiple sectors within the IO table. The bridge matrix defines these connections and makes the connection operationalizable. The bridge matrix can be either presented in matrix form or as a table classifying the demand vector values to IO table sectors.
16	Sensitivity and Uncertainty analysis	Quantitative analysis of uncertainty can add clarity and transparency to uncertainty reporting to the reader. Furthermore, it can help prioritize efforts to improve data quality in those areas of uncertainty which contribute most to the overall uncertainty of the results
17	Discussion of limitations	A variety of limitations can arise from CF calculations with IO models (e.g. insufficient data, high level of aggregation, etc.). Therefore, a critical discussion of limitations can increase transparency.

Full search strategies for all databases

DATABASE	SEARCH TERM
SCOPUS	TITLE-ABS(((footprint OR "carbon emission" OR "greenhouse gas*")) AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR "health services"))) OR ("input-output" AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR "health services")) AND ((footprint OR "carbon emission" OR "greenhouse gas*" OR environmental* extended))) AND NOT DOCTYPE(ed) AND NOT DOCTYPE(er) AND NOT DOCTYPE(le) AND NOT DOCTYPE(no) AND NOT DOCTYPE(pr)
WEB OF SCIENCE	TOPIC: ((((footprint OR "carbon emission" OR "greenhouse gas*")) AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR "health services"))) OR ("input-output" AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR "health services")) AND ((footprint OR "carbon emission" OR "greenhouse gas*" OR environmental* extended))))Timespan: All years. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC.
ECONBIZ	(((footprint OR "carbon emission" OR "greenhouse gas*")) AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR "health services"))) OR ("input-output" AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR "health services")) AND ((footprint OR "carbon emission" OR "greenhouse gas*" OR environmental* extended)))
PUBMED	Search (((footprint OR "carbon emission" OR "greenhouse gas*")) AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR "health services"))) OR ("input-output" AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR "health services")) AND ((footprint OR "carbon emission" OR "greenhouse gas*" OR environmental* extended)))

Appendix: System description and results

Please use Ctrl + Scroll to zoom in this electronic appendix

Author	Year	Title	Health Care System	Carbon Footprint	tCO2/capita	% of total emission	Breakdown
Nansai et al.	2020	Carbon footprint of Japanese health care services from 2011 to 2015	Japan	2011:62.5mt CO2 equivalent; 2012: 69,4mt CO2eq; 2013: 71 mt CO2eq; 2014 70.2mt CO2eq; 2015 72 mtCO2eq	c.n.	4,6% of the total domestic GHG emission	~Capital vs. Service: Service:86%; Capital formation 14% ~Broad Categories: Fixed Capital Formation: 15.92%; Nursing services 16.16%; Health and Hygiene : 1.3% ; Household medication; 2,4% ; Medical services 66,4% ~Detailed Categories: Medical services (hospitalization): 25.12%; Medical services (non-hospitalization): 22,72%; Medical services (pharmacy dispensing) 13.1%; Home medication: 1.84%; Nursing care (facility services) 6.64% ; Nursing care (excluding facility services): 9,47%; Private fixed capital formation for medical services 10,22%; Private fixed capital formation for nursing care 1.62%
Eckelman et al.	2016	Environmental Impacts of the U.S. Health Care System and Effects on Public Health	USA	2003:511 Mt CO2eq; 2004:529 Mt CO2eq; 2005:547 Mt CO2eq; 2006:563 Mt CO2eq; 2007:584 Mt CO2eq; 2008:600 Mt CO2eq; 2009: 608 Mt CO2eq; 2010:615 Mt CO2eq; 2011:626 Mt CO2eq; 2012:643 Mt CO2eq; 2013:655 Mt CO2eq	c.n.	2003: 7,2%; 2004: 7,3%; 2005: 7,6%; 2006: 7,8%; 2007: 8,0%; 2008: 8,5%; 2009: 9,2%; 2010: 9,0%; 2011: 9,3%; 2012: 9,9%; 2013: 9,8%;	Hospital Care: 36%; Physicians and Clinical Services: 12%; Prescription Drugs: 10%; Other Professional Services: 1,5%; Dental Services:1,6%; Other Health, Residential, Personal Care: 3,8%; Home Health Care: 2,5%; Nursing Care Facilities and Continuing Care Retirement Communities: 6%; Durable Medical Equipment: 2,6%; Other Non-Durable Medical Products: 2,2%; Government Administration: 2,2%; Net Cost Health Insurance: 1,3%; Government Public Health Activities: 4,3 %; Research: 1,6%;Structure and Equipment: 10,4%
Pichler et al.	2019	International comparison of health care carbon footprints	OECD (Australia; Austria; Belgium; Canada; Chile; Czech Republic; Germany; Denmark; Spain; Estonia; Finalnd; France; Great Britain; Greece; Hungary; Ireland; Iceland; Italy; Japan; Korea; Luxemburg; Latvia; Mexico; Netherlands; Norway; Poland; Portugal; Slovakia; Slovenia; Sweden; Turkey; United States; Israel; New Zealand); China; India	~Australia: 19,5 mtCO2e; ~Austria: 6,8 mtCO2e; ~Belgium: 7,5 mtCO2e; ~Canada: 29,7 mtCO2e; ~Chile: 5,9 mtCO2e; ~China: 600,6 mtCO2e; ~Czech Republic: 4,8 mtCO2e; ~Germany: 55,1 mtCO2e; ~Denmark: 4 mtCO2e; ~Spain: 19,2 mtCO2e; ~Estonia: 1,2 mtCO2e; ~Finland: 3,9 mtCO2e; ~France: 34,4 mtCO2e; ~Great Britain: 41,1 mtCO2e; ~Greece: 4,2 mtCO2e; ~Hungary: 2,9 mtCO2e; ~India: 74,1 mtCO2e; ~Ireland: 3,1 mtCO2e; ~Iceland: 0,2 mtCO2e; ~Italy: 23,1 mtCO2e; ~Japan: 114,9 mtCO2e; ~Korea: 33,1 mtCO2e; ~Luxemburg: 0,7 mtCO2e; ~Latvia: 0,5 mtCO2e; ~Mexico: 16,6 mtCO2e; ~Netherlands: 15,8 mtCO2e; ~Norway: 3,6 mtCO2e; ~Poland: 17,4 mtCO2e; ~Portugal: 4 mtCO2e; ~Slovakia: 4,1 mtCO2e; ~Slovenia: 0,7 mtCO2e; ~Sweden: 4,1 mtCO2e; ~Turkey: 17,8 mtCO2e; ~United States: 479,7 mtCO2e; ~Israel(2013): 3,5 mtCO2e; ~New Zealand (2017):1,8 mtCO2e	~Australia: 0.83 tCO2/cap; ~Austria: 0,8 tCO2/cap; ~Belgium: 0,66 tCO2/cap; ~Canada: 0,83 tCO2/cap; ~Chile: 0,73 tCO2/cap; ~China:0,44 tCO2/cap; ~Czech Republic: 0,46 tCO2/cap; ~Germany: 0,68 tCO2/cap; ~Denmark: 0,71 tCO2/cap; ~Spain: 0,41 tCO2/cap; ~Estonia: 0,88 tCO2/cap; ~Finland: 0,72 tCO2/cap; ~France: 0,52 tCO2/cap; ~Great Britain: 0,64 tCO2/cap; ~Greece: 0,39 tCO2/cap; ~Hungary: 0,29 tCO2/cap; ~India: 0,06 tCO2/cap; ~Ireland:0,68 tCO2/cap; ~Iceland: 0,61 tCO2/cap; ~Italy: 0,38 tCO2/cap; ~Japan: 0,9 tCO2/cap; ~Korea: 0,65 tCO2/cap; ~Luxemburg: 1,24 tCO2/cap; ~Latvia: 0,26 tCO2/cap; ~Mexico: 0,13 tCO2/cap; ~Netherlands: 0,93 tCO2/cap; ~Norway: 0,7 tCO2/cap ; ~Poland: 0,46 tCO2/cap; ~Portugal: 0,38 tCO2/cap; ~Slovakia: 0,75 tCO2/cap; ~Slovenia:0,35 tCO2/cap; ~Sweden: 0,42 tCO2/cap; ~Turkey: 0,23 tCO2/cap; ~United States: 1,51 tCO2/cap ; ~Israel(2013):0,43 tCO2/cap; ~New Zealand (2017):0,42 tCO2/cap	~Australia: 4,2%; ~Austria: 6,7%; ~Belgium: 7,7%; ~Canada:5,1%; ~Chile:5,9%; ~China: 6,6%; ~Czech Republic: 4,5%; ~Germany: 6,7%; ~Denmark:6,4%; ~Spain: 5,5%; ~Estonia: 5,2%; ~Finland: 5,3%; ~France: 6,9%; ~Great Britain: 5,9%; ~Greece: 3,8%; ~Hungary: 5,4%; ~India: 3,5%; ~Ireland: 6,7%; ~Iceland: 4,7%; ~Italy: 5,1%; ~Japan: 7,6%; ~Korea: 5,3%; ~Luxemburg: 3,6%; ~Latvia: 3,9%; ~Mexico:3,3%; ~Netherlands: 8,1%; ~Norway: 4,7%; ~Poland: 5,7%; ~Portugal:6%; ~Slovakia:6,7%; ~Slovenia: 4%; ~Sweden: 4,5%; ~Turkey: 3,9%; ~United States: 7,9%; ~Israel(2013): 4,4%; ~New Zealand (2017):4,1%	~Public health care: 62%; Private health care: 31%; Investment: 6% ~Broad Categories: Medical retail: 33%; Hospital; 28,6%; ambulatory health care services:18%; Others: 20%; ~Detailed Categories: Hospital Care: 2003: 184 (Mt CO2-e); 2004: 188; 2005: 195; 2006: 200; 2007: 206; 2008: 210; 2009: 218; 2010: 222; 2011: 226; 2012: 233; 2013: 238; Physician and Clinical Services: 2003: 57; 2004: 60; 2005: 195; 2006: 65; 2007:68; 2008: 68; 2009: 69; 2010: 70; 2011: 72; 2012: 74; 2013: 77; Other Professional Services: 2003: 7; 2004: 8; 2005: 8; 2006: 8; 2007: 8; 2008: 8; 2009: 9; 2010: 9; 2011: 9; 2012:10; 2013:10; Dental Services: 2003: 11; 2004: 12; 2005: 12; 2006: 12; 2007:12; 2008: 12; 2009: 12; 2010: 12; 2011: 12; 2012:12; 2013: 11; Other Health, Residential, and Personal Care: 2003: 20; 2004: 21; 2005: 22; 2006: 22; 2007: 23; 2008: 23; 2009: 24; 2010: 25; 2011: 25; 2012:25; 2013: 26; Home Health Care: 2003: 9; 2004: 10; 2005: 11; 2006: 12; 2007: 13; 2008: 13; 2009: 14; 2010: 15; 2011: 15; 2012: 16; 2013: 17; Nursing Care Facilities and Continuing Care Retirement Communities: 2003: 35; 2004: 36; 2005: 37; 2006: 37; 2007: 38; 2008: 39; 2009: 39; 2010: 39; 2011: 40; 2012: 40; 2013: 41; Prescription Drugs: 2003: 59; 2004: 63; 2005: 65; 2006: 68; 2007: 71; 2008: 71; 2009: 72; 2010: 69; 2011: 68; 2012: 67; 2013: 68; Durable Medical Equipment: 2003: 12; 2004:13; 2005: 14; 2006: 15; 2007: 16; 2008: 16; 2009: 16; 2010: 16; 2011: 17; 2012: 17; 2013: 18; Other Non-Durable Medical Products: 2003: 11; 2004: 11; 2005: 12; 2006: 12; 2007: 13; 2008: 13; 2009: 13; 2010: 13; 2011: 14; 2012: 15; 2013: 15; Government Administration: 2003: 13; 2004: 13; 2005: 14; 2006: 13; 2007: 13; 2008: 13; 2009: 13; 2010: 13; 2011: 14; 2012: 14; 2013: 15; Net Cost of Health Insurance: 2003: 7; 2004: 7; 2005: 7; 2006: 8; 2007: 8; 2008: 8; 2009: 8; 2010: 8; 2011: 8; 2012: 8; 2013:9; Government Public Health Activities: 2003: 28; 2004: 28; 2005: 28; 2006: 28; 2007: 29; 2008:30; 2009: 31; 2010: 31; 2011: 29; 2012:29; 2013: 29; Research: 2003: 12; 2004: 12; 2005: 13; 2006: 12; 2007: 12; 2008: 12; 2009: 12; 2010: 13; 20111: 12; 2012: 12; 2013: 11; Structures and Equipment: 2003: 45; 2004: 47; 2005: 50; 2006: 51; 2007: 57; 2008: 62; 2009: 59; 2010: 60; 2011: 65; 2012: 70; 2013: 71;
Eckelman et al.	2018	Life cycle environmental emissions and health damages from the Canadian healthcare system: An economic-environmental-epidemiological analysis	Canada	2009:29,6million Mt CO2e; 2010: 31,2; 2011: 31,4; 2012:31,5; 2013:31,4; 2014:32,0; 2015:33,0;	2014: 0.9; n.c.	2014: 4,6%; n.c.	Hospitals (Private): 2009: 0,7 million Mt CO2e; 2010: 0,7; 2011: 0,7; 2012: 0,7; 2013: 0,7; 2014: 0,8; 2015: 0,8; Hospitals (Public): 2009: 6,5; 2010: 6,8; 2011: 7,0; 2012: 7,0; 2013: 7,1; 2014: 7,1; 2015: 7,1; Other Institutions (Private): 2009: 0,7; 2010: 0,7; 2011: 0,7; 2012: 07; 2013: 0,8; 2014: 0,8; 2015: 0,9; Other Institutions (Public): 2009: 1,1; 2010: 1,2; 2011: 1,2; 2012: 1,2; 2013: 1,2; 2014: 1,2; 2015: 1,3; Physicians: 2009: 3,7; 2010: 3,9; 2011: 4,0; 2012: 4,1; 2013: 4,2; 2014: 4,3; 2015: 4,4; Dental Services: 2009: 1,7; 2010: 1,7; 2011: 1,6; 2012: 1,7; 2013: 1,7; 2014: 1,7; 2015: 1,8; Vision Care Services: 2009: 0,6; 2010: 0,5; 2011: 0,5; 2012: 0,5; 2013: 0,5; 2014: 0,5; 2015. 0,6; Other: 2009: 0,4; 2010: 0,4; 2011: 0,4; 2012: 0,5; 2013: 0,5; 2014: 0,5; 2015: 0,6; Prescribed Drugs: 2009: 6,3; 2010: 6,9; 2011: 6,8; 2012: 6,7; 2013: 6,7; 2014: 6,8; 2015: 7,0; Nonprescribed Drugs: 2009: 1,2; 2010: 1,2; 2011:1,2; 2012: 1,2; 2013: 1,2; 2014: 1,2; 2015: 1,3; Capital: 2009: 2,5; 2010: 2,8; 2011: 2,7; 2012: 2,7; 2013: 2,3; 2014: 2,3; 2015: 2,4; Public Health: 2009: 1,6; 2010: 1,6; 2011: 1,7; 2012: 1,7; 2013: 1,7; 2014: 1,8; 2015: 1,9; Administration: 2009: 0,7; 2010: 0,7; 2011: 0,7; 2012: 0,7; 2013: 0,7; 2014: 0,7; 2015: 0,6; Health Research: 2009: 0,4; 2010: 0,4; 2011: 0,4; 2012: 0,4; 2013: 0,4; 2014: 0,4; 2015: 0,4; Other: 2009: 1,6; 2010: 1,7; 2011: 1,7; 2012: 1,7; 2013: 1,7; 2014: 1,8; 2015: 2,0;
Malik et al.	2018	The carbon footprint of Australian health care	Australia	~2013: 33.796 kt CO2e(0,034mt co2e); ~2014: 34.840 kt CO2 (0,035 co2e); ~2015: 35.772 kt CO2e (0,036 co2e) ;	c.n.	7%	~2013: Public Hospital 34,59%; Private Hospitals 9,62%; All other medications 9,25%; Benefit paid Pharmaceuticals 9,81%; Capital expenditures (Buildings) 7,61%; Referred medicals services 5,88%; Community Health and other 5,29%; General Practice 4,21%; Dental services 3,28%; Aids and Appliances 2,88%; Other health practitioner 2,23%; Research 2,1%; Administration 1,3%; Patient Transport Services 1,16%; Public Health 0,83%; ~2014: Public Hospital 34,35%; Private Hospitals 9,79%; All other medications 9,21%; Benefit paid Pharmaceuticals 9,61%; Capital expenditures (Buildings) 7,72%; Referred medicals services 5,99%; Community Health and other 5,25%; General Practice 4,2%; Dental services 3,22%; Aids and Appliances 2,97%; Other health practitioner 2,16%; Research 2,16%; Administration 1,39%; Patient Transport Services 1,16%; Public Health 0,82%; ~2015: Public Hospital 34,36%; Private Hospitals 10,16%; All other medications 9,35%; Benefit paid Pharmaceuticals 9,1%; Capital expenditures (Buildings) 7,76%; Referred medicals services 6,06%; Community Health and other 5,16%; General Practice 4,22%; Dental services 3,31%; Aids and Appliances 2,95%; Other health practitioner 2,16%; Research 1,94%; Administration 1,43%; Patient Transport Services 1,19%; Public Health 0,82%;
Wu	2019	The carbon footprint of the Chinese health-care system: an environmentally extended input-output and structural path analysis study	China	315 Mt CO2e	0,2	2,70%	~Hospitals 51%; Public Hospitals 47%; Private Hospitals 4%; ~NHP pharmaceuticals 18% ~Community health care 10% ~Public Health 4% ~Other health-care institutions 1% ~Construction 15% ~Research 0,3% ~Administration 0,7%
NHSScotland	2008	National Health Service Scotland Carbon Footprint of NHS Scotland(1990-2004)	Scotland	~1998: 2,74 mt CO2e; ~1998: 2,57 mt CO2e; ~2004: 2,63 mt CO2e	c.n.	3,60%	~Scotland: ~1990: ~Travel 23,73%: Patient own travel 10,95%; Visitor Travel 4,75%; Staff Commuting 2,19%; NHS Travel business 6,21%; ~Building Energy Use 34,31%: Grid-supplied electricity 7,3%; On-site fossil fuel gas 6,94%; On-site fossil fuel oil 10,95%; On-site fossil fuel coal 8,76%; Renewables n.d.; ~Procurement 41,98%: Pharmaceuticals 12,41%; Medical Instruments/equipment 5,48%; Health Services 5,11%; Freight Transport 0,37%; Business Services 3,65%; Paper Products 3,29%; Other Manufactured Products 2,56%; Manufactured fuels, chemical, glasses 1,83%; Food and catering 2,92%; Construction 1,46%; Information and communication technologies 0,73%; Water and Sanitation 0,73%; Waste products and recycling 0,37%; Other Procurement 1,1%; ~1998: ~Travel 27,63%: Patient own travel 12,84 %; Visitor Travel 5,84%; Staff Commuting 2,72%; NHS Travel business 5,84%; ~Building Energy Use 26,07%: Grid-supplied electricity 8,56%; On-site fossil fuel gas 12,06%; On-site fossil fuel oil 4,28%; On-site fossil fuel coal 1,17%; Renewables n.d.; ~Procurement 46,30%: Pharmaceuticals 14,4%; Medical Instruments/equipment 7%; Health Services 4,67%; Freight Transport 0,39%; Business Services 4,67%; Paper Products 3,5%; Other Manufactured Products 2,33%; Manufactured fuels, chemical, glasses 1,56%; Food and catering 2,33%; Construction 1,95%; Information and Communication technologies 0,78%; Water and Sanitation 0,78%; Waste products and recycling 0,39%; Other Procurement 1,56; ~2004: ~Travel 24%: Patient own travel 10%; Visitor Travel 6%; Staff commuting 3%; NHS travel business 6%; ~Building Energy Use 23%; Grid-supplied Electricity 9%; On-site fossil fuels gas 12%; On-site fossil fuels oil 2%; On-site fossil fuels coal 0%; Renewables 0%; ~Procurement 52%; Pharmaceuticals 18%; Medical instruments/equipment 7%;Health Services 6%; Freight Transport 0%; Business Service 5%; Paper Products 4%; Other manufactured products 3%; Manufactured fuels, chemicals, glasses 2%; Food and catering 2%; Construction 2%; Information and Communication Technology 1%; Water and Sanitation 1%; Waste Products and Recycling 0%; Other Procurement 1%; ~England 2004: ~Travel 18%: Patient own travel 8%; Visitor Travel 2%; Staff Commuting 4%; NHS Travel business 4%; ~Building Energy Use 22%: Grid-supplied electricity 12%; On-site fossil fuel gas 9%; On-site fossil fuel oil 1%; On-site fossil fuel coal 0%; Renewables 0%; ~Procurement 59%: Pharmaceuticals 12% Medical Instruments/equipment 12%; Health Services n/a; Freight Transport 4%; Business Services 5%; Paper Products 5%; Other Manufactured Products 3%; Manufactured fuels, chemical, glasses 3%; Food and catering 2%; Construction 2%; Information and Communication technologies 2%; Water and Sanitation 1%; Waste products and recycling 1%; Other Procurement 1%
SDU series	2016	Carbon update for the health and care sector in England 2015(1)	NHS England	~1992: 16.58 Mt CO2 ~1993: 15.46 Mt CO2 ~1994: 15.52 Mt CO2 ~1995: 15.48 Mt CO2 ~1996: 15.93 Mt CO2 ~1997: 15.40 Mt CO2 ~1998: 15.77 Mt CO2 ~1999: 16.62 Mt CO2 ~2000: 16.51 Mt CO2 ~2001: 17.97 Mt CO2 ~2002: 17.33 Mt CO2 ~2003: 18.36 Mt CO2 ~2004: 18.62 Mt CO2 ~2007: 21.2 Mt CO2 ~2012: 25 Mt CO2 ~2014: 24.7 Mt CO2 ~2015: 26,6 Mt CO2 ~2017: 27,119 Mt CO2	c.n.	c.n.	~Building Energy Use 18%; ~Travel 13%; ~Commissioned health and care Services from outside system 11%; ~Procurement 57%: Pharmaceuticals (excluding Meter Dose Inhalers) 11%; Business Services 11%; Medical Instruments/Equipment 10%; Food and Catering 5%; Freight Transport 3%; Meter Dose Inhalers 3%; Construction 2%; Manufactured fuels, chemicals and glasses 2%; Paper Products 2%; Waste Products and Recycling 2%; Anaesthetic gases 2%; Other manufactured products 2%, Information and communication Technology 2%; Water and Sanitation 1%
HCH	2019	Health Care´s Climate Footprint	Global; Australia; Austria; Belgium; Brazil; Bulgaria; Canada; China; Croatia; Cyprus; Czech Repub-lic; Denmark; Estonia; Finland; France; Germany; Greece; Hungary; India; Indonesia; Ireland; Italy; Japan; Latvia; Lithuania; Luxembourg; Malta; Mexico; Netherlands; Norway; Poland; Portugal; Romania; Russia; Slovak Republic; Slovenia; Spain; South Korea; Sweden; Switzer-land; Taiwan; Turkey; United Kingdom; United States; Rest-of-World; European Union	Global 2 Gt United States 546.54 Mt; China 342.46Mt; European Union 248.52Mt; Japan 103.55Mt; Russian Federation 76.46Mt; Germany 57.51Mt; Brazil 43.84Mt; United Kingdom 42.5Mt; India 38.8Mt; South Korea 37.26Mt; Canada 35.96Mt; Australia 30.17Mt; France 28.98Mt; Mexico 22.53Mt; Italy 21.31Mt; Spain 16.72Mt; Turkey 14.83Mt; Indonesia 13.59Mt; Netherlands 13.32Mt; Poland 13.02Mt; Taiwan 12.27Mt; Belgium 9.3Mt; Switzerland 8.32Mt; Austria 5.04Mt; Sweden 4.5Mt; Denmark 4.4Mt; Greece 4.15Mt; Czech Republic 3.71Mt; Portugal 3.61Mt; Finland 3.51Mt; Romania 3.08Mt; Norway 3.08Mt; Ireland 2.83Mt; Bulgaria 2.7Mt; Hungary 2.55Mt; Slovak Republic 1.19Mt; Slovenia 0.93Mt; Estonia 0.86Mt; Croatia 0.8Mt; Lithuania 0.5Mt; Latvia 0.5Mt; Luxembourg 0.47Mt; Cyprus 0.34Mt; Malta 0.2Mt	Global 0,28 t CO2e; Australia 1,29 tCO2e; Austria 0,59 tCO2e; Belgium 0,83 tCO2e; Brazil 0,21 tCO2e; Bulgaria 0,37 tCO2e; Canada 1,01 tCO2e; China 0,25 tCO2e; Croatia 0,19 tCO2e; Cyprus 0,3 tCO2e; Czech Republic 0,35 tCO2e; Denmark 0,78 tCO2e; Estonia 0,66 tCO2e; Finland 0,64 tCO2e; France 0,44 tCO2e; Germany 0,71 tCO2e; Greece 0,38 tCO2e; Hungary 0,26 tCO2e; India 0,03 tCO2e; Indonesia 0,05 tCO2e; Ireland 0,61 tCO2e; Italy 0,35 tCO2e; Japan 0,81 tCO2e; Latvia 0,25 tCO2e; Lithuania 0,17 tCO2e; Luxembourg 0,84 tCO2e; Malta 0,45 tCO2e; Mexico 0,18 tCO2e; Netherlands 0,79 tCO2e; Norway 0,64tCO2e; Poland 0,34 tCO2e; Portugal 0,35 tCO2e; Romania 0,15 tCO2e; Russia 0,53 tCO2e; Slovak Republic 0,22 tCO2e; Slovenia 0,45 tCO2e; Spain 0,36 tCO2e; South Korea 0,73 tCO2e; Sweden 0,46 tCO2e; Switzerland 1,02 tCO2e; Taiwan 0,52 tCO2e; Turkey 0,19 tCO2e; United Kingdom 0,66 tCO2e; United States 1,72 tCO2e; Rest-of-World 0,16 tCO2e; European Union 0,49 tCO2e;	United States 7,6; China 3,1; European Union 4,7; Japan 6,4; Russian Federation 4; Germany 5,2; Brazil 4,4; United Kingdom 5,4; India 1,5; South Korea 5,3; Canada 5,2; Australia 5,1; France 4,6; Mexico 3,4; Italy 4; Spain 4,5; Turkey 3,2; Indonesia 1,9; Netherlands 5,9; Poland 3,7; Taiwan 4,6; Belgium 5,5; Switzerland 6,7; Austria 5,2; Sweden 4,4; Denmark 6,3; Greece 3,7; Czech Republic ;3,6 Portugal 4,8; Finland 5; Romania 2,7; Norway 4,3; Ireland 4,4; Bulgaria 6; Hungary 4,3; Slovak Republic 2,8; Slovenia 4,6; Estonia 4,7; Croatia 3,2; Lithuania 2; Latvia 3,2; Luxembourg 3,7; Cyprus 2,9; Malta 4,8; Global 4,4%	~~Scopes ~Global 2,0 gt CO2e: ~Health care facilities and health care owend vehicles 17%; Indirect Emissions 12%; Procurement 71%; ~Australia: Scope1 19%; Scope2 9%; Scope3 72%; ~Austria: Scope1 7%; Scope2 6%; Scope3 87%; ~Belgium: Scope1 11%; Scope2 9%; Scope3 80%; ~Brazil: Scope1 21%; Scope2 6%; Scope3 73%; ~Bulgaria: Scope1 6%; Scope2 43%; Scope3 51%; ~Canada: Scope1 26%; Scope2 13%; Scope3 61%; ~China: Scope1 13%; Scope2 7%; Scope3 80%; ~Croatia: Scope1 17%; Scope2 12%; Scope3 71%; ~Cyprus: Scope1 6%; Scope2 16%; Scope3 78%; ~Czech Republic: Scope1 12%; Scope2 5%; Scope3 83%; ~Denmark: Scope1 12%; Scope2 8%; Scope3 80%; ~Estonia: Scope1 6%; Scope2 51%; Scope3 43%; ~Finland: Scope1 5%; Scope2 13%; Scope3 82%; ~France: Scope1 12%; Scope2 5%; Scope3 83%; ~Germany: Scope1 16%; Scope2 18%; Scope3 66%; ~Greece: Scope1 14%; Scope2 24%; Scope3 62%; ~Hungary: Scope1 16%; Scope2 13%; Scope3 71%; ~India: Scope1 8%; Scope2 11%; Scope3 81%; ~Indonesia: Scope1 16%; Scope2 8%; Scope3 76%; ~Ireland: Scope1 13%; Scope2 9%; Scope3 78%; ~Italy: Scope1 9%; Scope2 8%; Scope3 83%; ~Japan: Scope1 16%; Scope2 17%; Scope3 67%; ~Latvia: Scope1 16%; Scope2 8%; Scope3 76%; ~Lithuania: Scope1 19%; Scope2 9%; Scope3 72%; ~Luxembourg: Scope1 14%; Scope2 4%; Scope3 82%; ~Malta: Scope1 7%; Scope2 11%; Scope3 82%; ~Mexico: Scope1 18%; Scope2 34%; Scope3 48%; ~Netherlands: Scope1 12%; Scope2 5%; Scope3 83%; ~Norway: Scope1 12%; Scope2 4%; Scope3 84%; ~Poland: Scope1 12%; Scope2 31%; Scope3 57%; ~Portugal: Scope1 12%; Scope2 5%; Scope3 83%; ~Romania: Scope1 12%; Scope2 10%; Scope3 78%; ~Russia: Scope1 7%; Scope2 31%; Scope3 62%; ~Slovak Republic: Scope1 20%; Scope2 4%; Scope3 76%; ~Slovenia: Scope1 11%; Scope2 12%; Scope3 77%; ~Spain: Scope1 12%; Scope2 5%; Scope3 83%; ~South Korea: Scope1 12%; Scope2 13%; Scope3 75%; ~Sweden: Scope1 12%; Scope2 5%; Scope3 83%; ~Switzerland: Scope1 10%; Scope2 5%; Scope3 85%; ~Taiwan: Scope1 11%; Scope2 26%; Scope3 63%; ~Turkey: Scope1 2%; Scope2 15%; Scope3 83%; ~United Kingdom: Scope1 12%; Scope2 5%; Scope3 83%; ~United States: Scope1 21%; Scope2 15%; Scope3 64%; ~Rest-of-World: Scope1 %; Scope2 %; Scope3 %; ~European Union: Scope1 14%; Scope2 11%; Scope3 75% ~~Economic Sectors: Generation and distribution of electricity, gas and heat or cooling 40%; Health care facilities operational emissions 13%; Other manufacturing 11%; Agriculture 9%; Other sectors and services 8%; Transport 7%; Pharmaceutical and chemical products 5%; Waste treatment 3%; Other primary Industry 3%
Weisz et al.	2020	Carbon emission trends and sustainability options in Austrian health care	Austria	6.8 Mt CO2eq	0.8t	7%	Hospitals 32%; Investments 9%; Medical retail 20%; Other 20%; Ambulatory 18%
Malik et al.	2021	Environmental impacts of Australia's largest health system	New South Wales, Australia	7908t CO2eq	c.n.	6,6%	-
Eckelman et al.	2020	Health Care Pollution And Public Health Damage In The United States: An Update	USA	2010: 520.5Mt CO2eq; 2011: 514.2 CO2eq; 2012: 486.6 CO2eq; 2013; CO2eq; 2014: 518.6 CO2eq; 2015: 525.6 CO2eq; 2016: 529.8 CO2eq; 2017: 538.1 CO2eq; 2018: 553.5 CO2eq	c.n.	c.n.	~~NHE expenditure categories: ~2010: Hospital care: 35.64%; Physician and Clinical Services: 11.47%; Other Professional Services: 2.21%; Dental Services: 3.05%; Other Health, Residential, and Personal Care: 6.72%; Home Health Care: 1.73%; Nursing Home Facilities and Continuing Care Retirement Communities: 6.99%; Prescription Drugs: 11.41%; Durable Medical Equipment: 1.77%; Other Non-Durable Medical Products: 2.46%; Federal Administration Expenditures: 1.44%; State and Local Administration Expenditures: 0.56%; Net Cost of Health Insurance: 1.31%; Public Health Activity: 5.05%; Research: 2.07%; Structures and Equipment: 6.11% ~2011: Hospital care: 35.57%; Physician and Clinical Services: 11.65%; Other Professional Services: 2.26%; Dental Services: 3.01%; Other Health, Residential, and Personal Care: 6.55%; Home Health Care: 1.79%; Nursing Home Facilities and Continuing Care Retirement Communities: 6.94%; Prescription Drugs: 11.09%; Durable Medical Equipment: 1.85%; Other Non-Durable Medical Products: 2.57%; Federal Administration Expenditures: 1.54%; State and Local Administration Expenditures:0.60%; Net Cost of Health Insurance: 1.24%; Public Health Activity: 4.80%; Research: 2.00%; Structures and Equipment: 6.59% ~2012: Hospital care: 35.64%; Physician and Clinical Services: 11.73%; Other Professional Services: 2.26%; Dental Services: 2.92%; Other Health, Residential, and Personal Care: 6.62%; Home Health Care: 1.81%; Nursing Home Facilities and Continuing Care Retirement Communities: 6.76%; Prescription Drugs: 10.81%; Durable Medical Equipment: 1.85%; Other Non-Durable Medical Products: 2.57%; Federal Administration Expenditures: 1.54%; State and Local Administration Expenditures:0.58%; Net Cost of Health Insurance: 1.27%; Public Health Activity: 4.81%; Research: 1.85%; Structures and Equipment: 6.99% ~2013: Hospital care: 35.73%; Physician and Clinical Services: 11.76%; Other Professional Services: 2.24%; Dental Services: 2.81%; Other Health, Residential, and Personal Care: 6.67%; Home Health Care 1.84%; Nursing Home Facilities and Continuing Care Retirement Communities: 6.71%; Prescription Drugs: 10.46%; Durable Medical Equipment: 1.86%; Other Non-Durable Medical Products: 2.59%; Federal Administration Expenditures: 1.6%; State and Local Administration Expenditures: 0.64%; Net Cost of Health Insurance: 1.34%; Public Health Activity: 4.73%; Research: 1.72%; Structures and Equipment: 7.25% ~2014: Hospital care: 35.27%; Physician and Clinical Services: 11.9%; Other Professional Services: 2.28%; Dental Services: 2.7%; Other Health, Residential, and Personal Care: 6.52%; Home Health Care 1.87%; Nursing Home Facilities and Continuing Care Retirement Communities: 6.46%; Prescription Drugs: 11.61%; Durable Medical Equipment: 2.06%; Other Non-Durable Medical Products: 2.7%; Federal Administration Expenditures: 1.72%; State and Local Administration Expenditures: 0.69%; Net Cost of Health Insurance: 1.33%; Public Health Activity: 4.69%; Research: 1.58%; Structures and Equipment: 6.61% ~2015: Hospital care: 34.84%; Physician and Clinical Services: 12.04%; Other Professional Services: 2.25%; Dental Services: 2.59%; Other Health, Residential, and Personal Care: 6.6%; Home Health Care1.86%; Nursing Home Facilities and Continuing Care Retirement Communities: 6.18%; Prescription Drugs: 12.27%; Durable Medical Equipment: 2.05%; Other Non-Durable Medical Products: 2.74%; Federal Administration Expenditures: 1.73%; State and Local Administration Expenditures: 0.65%; Net Cost of Health Insurance: 1.29%; Public Health Activity: 4.74%; Research: 1.48%; Structures and Equipment: 6.66% ~2016: Hospital care: 35.05%; Physician and Clinical Services: 12.31%; Other Professional Services:2.27%; Dental Services: 2.57%; Other Health, Residential, and Personal Care: 6.61%; Home Health Care 1.85%; Nursing Home Facilities and Continuing Care Retirement Communities: 6.02%; Prescription Drugs: 12.12%; Durable Medical Equipment: 2.06%; Other Non-Durable Medical Products: 2.79%; Federal Administration Expenditures: 1.72%; State and Local Administration Expenditures: 0.66%; Net Cost of Health Insurance: 1.26%; Public Health Activity: 4.66%; Research: 1.45%; Structures and Equipment: 6.61% ~2017: Hospital care: 35.01%; Physician and Clinical Services: 12.47%; Other Professional Services: 2.27%; Dental Services: 2.55%; Other Health, Residential, and Personal Care: 6.69%; Home Health Care 1.88%; Nursing Home Facilities and Continuing Care Retirement Communities: 5.82%; Prescription Drugs: 11.89%; Durable Medical
Tennison et al.	2021	Health care's response to climate change: a carbon footprint assessment of the NHS in England	England	~1990: 33.8 Mt CO2eq ~1991: 33 Mt CO2eq ~1992: 33.2 Mt CO2eq ~1993: 30.8 Mt CO2eq ~1994:30.3 Mt CO2eq ~1995:30.4 Mt CO2eq ~1996: 29.4 Mt CO2eq ~1997 29.3 Mt CO2eq ~1998: 27.8 Mt CO2eq ~1999: 28.2 Mt CO2eq ~2000:27.5 Mt CO2eq ~2001: 26.8 Mt CO2eq ~2002: 26.1 Mt CO2eq ~2003: 27 Mt CO2eq ~2004: 27.1 Mt CO2eq ~2005: 27.6 Mt CO2eq ~2006: 27 Mt CO2eq ~2007: 28.3 Mt CO2eq ~2008: 28.7 Mt CO2eq ~2009: 28.4 Mt CO2eq ~2010: 28.1 Mt CO2eq ~2011: 27.3 Mt CO2eq ~2012: 27.9 Mt CO2eq ~2013: 28.3 Mt CO2eq ~2014: 28.3 Mt CO2eq ~2015: 27.3 Mt CO2eq ~2016: 26.4 Mt CO2eq ~2017: 25.7 Mt CO2eq ~2018: 25.4 Mt CO2eq ~2019 25 Mt CO2eq	~1990: 0.709 ~1991: 0.689 ~1992: 0.696 ~1993: 0.640 ~1994: 0.629 ~1995: 0.628 ~1996: 0.603 ~1997: 0.603 ~1998: 0.57 ~1999: 0.574 ~2000: 0.558 ~2001: 0.542 ~2002: 0.526 ~2003: 0.54 ~2004: 0.54 ~2005: 0.546 ~2006: 0.529 ~2007: 0.552 ~2008: 0.554 ~2009: 0.544 ~2010: 0.535 ~2011: 0.514 ~2012: 0.522 ~2013: 0.525 ~2014: 0.515 ~2015: 0.498 ~2016: 0.478 ~2017: 0.463 ~2018: 0.454 ~2019: 0.445	c.n.	~1990: Delivery of care: 47.93%; Supply Chain: 46.15%; Commissioned Healthcare: 0.56%; Travel: 5.62% ~1991: Delivery of care: 47.27%; Supply Chain: 46.06%; Commissioned Healthcare: 0.61%; Travel: 6.06% ~1992: Delivery of care: 45.81%; Supply Chain: 47.60%; Commissioned Healthcare: 0.60%; Travel: 5.99% ~1993: Delivery of care: 45.78%; Supply Chain: 46.75%; Commissioned Healthcare: 0.65%; Travel: 6.49% ~1994: Delivery of care: 46.20%; Supply Chain: 46.53%; Commissioned Healthcare: 0.66%; Travel: 6.93% ~1995: Delivery of care: 43.09%; Supply Chain: 49.01%; Commissioned Healthcare: 0.99%; Travel: 6.91% ~1996: Delivery of care: 44.03%; Supply Chain: 47.44%; Commissioned Healthcare: 1.02%; Travel: 7.17% ~1997: Delivery of care: 41.63%; Supply Chain: 50.51%; Commissioned Healthcare: 1.02%; Travel: 7.51% ~1998: Delivery of care: 44.96%; Supply Chain: 46.40%; Commissioned Healthcare: 1.08%; Travel: 7.91% ~1999: Delivery of care: 43.62%; Supply Chain: 47.16%; Commissioned Healthcare: 1.06%; Travel: 7.80% ~2000: Delivery of care: 41.45%; Supply Chain: 49.09%; Commissioned Healthcare: 1.09%; Travel: 8.36% ~2001: Delivery of care: 41.04%; Supply Chain: 49.25%; Commissioned Healthcare: 1.12%; Travel: 8.58% ~2002: Delivery of care: 40.61%; Supply Chain: 49.81%; Commissioned Healthcare: 1.15%; Travel: 8.43% ~2003: Delivery of care: 40.00%; Supply Chain: 49.63%; Commissioned Healthcare: 1.48%; Travel: 8.89% ~2004: Delivery of care: 37.27%; Supply Chain: 52.77%; Commissioned Healthcare: 1.48%; Travel: 8.49% ~2005: Delivery of care: 38.77%; Supply Chain: 50.72%; Commissioned Healthcare: 1.45%; Travel: 9.06% ~2006: Delivery of care: 38.15%; Supply Chain: 50.74%; Commissioned Healthcare: 1.48%; Travel: 9.63% ~2007: Delivery of care: 34.63%; Supply Chain: 54.42%; Commissioned Healthcare: 1.77%; Travel: 9.54% ~2008: Delivery of care: 33.10%; Supply Chain: 56.10%; Commissioned Healthcare: 1.74%; Travel: 9.06% ~2009: Delivery of care: 33.10%; Supply Chain: 56.69%; Commissioned Healthcare: 2.11%; Travel: 8.10% ~2010: Delivery of care: 30.96%; Supply Chain: 58.01%; Commissioned Healthcare: 2.49%; Travel: 8.90% ~2011: Delivery of care: 30.40%; Supply Chain: 57.14%; Commissioned Healthcare: 4.03%; Travel: 8.42% ~2012: Delivery of care: 31.54%; Supply Chain: 56.27%; Commissioned Healthcare: 3.94%; Travel: 8.24% ~2013: Delivery of care: 28.98%; Supply Chain: 57.95%; Commissioned Healthcare: 4.59%; Travel: 8.48% ~2014: Delivery of care: 27.86%; Supply Chain: 58.93%; Commissioned Healthcare: 4.29%; Travel: 8.57% ~2015: Delivery of care: 27.11%; Supply Chain: 60.44%; Commissioned Healthcare: 4.03%; Travel: 8.79% ~2016: Delivery of care: 26.52%; Supply Chain: 60.61%; Commissioned Healthcare: 3.79%; Travel: 9.09% ~2017: Delivery of care: 26.07%; Supply Chain: 61.09%; Commissioned Healthcare: 3.89%; Travel: 9.34% ~2018: Delivery of care: 25.20%; Supply Chain: 61.42%; Commissioned Healthcare: 3.94%; Travel: 9.45% ~2019: Delivery of care: 24.40%; Supply Chain: 62.40%; Commissioned Healthcare: 4.00%; Travel: 9.60%
Lenzen et al.	2020	The environmental footprint of health care: a global assessment	Global (189 countries)	~2000: Global: 1.70Gt CO2eq ~2001: Global: 1.70Gt CO2eq ~2002: Global: 1.76Gt CO2eq ~2003: Global: 1.87Gt CO2eq ~2004: Global: 1.87Gt CO2eq ~2005: Global: 1.92Gt CO2eq ~2006: Global: 1.98Gt CO2eq ~2007: Global: 2.04Gt CO2eq ~2008: Global: 2.04Gt CO2eq ~2009: Global: 1.98Gt CO2eq ~2010: Global: 2.10Gt CO2eq ~2011: Global: 2.14Gt CO2eq ~2012: Global: 2.19Gt CO2eq ~2013: Global:2.24Gt CO2eq ~2014: Global:2.29Gt CO2eq ~2015: Global:2.40Gt CO2eq; USA: 595.14Mt Co2eq; Japan: 190.52Mt Co2eq; Germany: 64.01Mt Co2eq; China: 375.50Mt Co2eq; France: 24.84Mt Co2eq; UK: 42.31Mt Co2eq; Russia: 219.64Mt Co2eq; Brazil: 103.28Mt Co2eq; Italy: 18.57Mt Co2eq; Canada: 43.09Mt Co2eq; Australia: 21.77Mt Co2eq; Spain: 31.32Mt Co2eq; Netherlands: 13.38Mt Co2eq; Norway: 4.23Mt Co2eq; Belgium: 7.22Mt Co2eq; Mexico: 16.55Mt Co2eq; Argentina: 16.38Mt Co2eq; Austria: 6.60Mt Co2eq; Israel: 6.65Mt Co2eq; Finland: 5.10Mt Co2eq; Poland: 13.20Mt Co2eq; South Korea: 24.88Mt Co2eq; Turkey: 11.95Mt Co2eq; Colombia: 5.08Mt Co2eq; Ireland: 3.91Mt Co2eq; Singapore: 8.60Mt Co2eq; Portugal 4.84Mt Co2eq; Thailand 13.36Mt Co2eq; Iran: 39.31Mt Co2eq; Indonesia: 14.29Mt Co2eq; Denmark: 3.37Mt Co2eq; South Africa: 15.93Mt Co2eq; Chile: 5.46Mt Co2eq; Greece: 4.00Mt Co2eq; New Zealand: 3.45Mt Co2eq; Czech Republic: 5.68Mt Co2eq; Taiwan: 10.49Mt Co2eq;	Norway: 0.81; Sweden: 0.58; Switzerland: 0.76; USA: 1.86; Finland: 0.93; Australia: 0.91; Netherlands: 0.79; Germany: 0.78; Belgium: 0.64; Japan: 1.49; Ireland: 0.83; Canada: 1.18; France: 0.37; Austria: 0.76; Israel: 0.82; Singapore: 1.55; Greenland: 76.99; UK 0.65; Denmark: 0.59; Italy: 0.31; New Zealand: 0.75; Spain: 0.67; Portugal: 0.46; Slovenia: 0.43; Curacao: 15.44; Russia: 1.53; Malta: 0.55; Uruguay: 0.79; Greece: 0.36; Czech Republic: 0.54; Slovakia: 1.27; Estonia 0.65; Hungary: 0.3; Chile: 0.31; Brazil: 0.5; Argentina: 0.38; Latvia: 0.36; Lithuania: 0.45; Poland: 0.35; South Korea: 0.49; Romania: 0.29; Colombia: 0.11; Mexico: 0.13; Taiwan: 0.45; Mauritius: 0.36; The former Yugoslav Republic of Macedonia: 0.36; Kazakhstan: 0.41; Turkey: 0.15; South Africa: 0.29; Thailand: 0.19; Malaysia: 0.25; China: 0.27; Georgia: 0.21; Iran: 0.50; Peru: 0.14; Ecuador: 0.09; Kuwait: 0.39; Ukraine: 0.27; Paraguay: 0.14; Venezuela: 0.15; Phillippines: 0.05; Kenya: 0.04; Uzbekuistan: 0.11; Indonesia: 0.06; India: 0.22; Viet Nam: 0.16	USA: 6.69%; Japan: 7.07%; Germany: 4.51%; China 3.1%; France: 3.19%; UK: 5%; Russia: 10.66%; Brazil: 3.11%; Italy: 2.31%; Canada: 4.76%; Australia: 3.25%; Spain: 5.39%; Netherlands: 4.02%; Sweden: 4.46%; India: 7.79%; Switzerland: 4.82%; Norway: 4.39%; Belgium: 3.45%; Mexico: 2.03%; Argentina: 3.88%; Austria: 4.54%; Israel: 4.99%; Finland: 4.26%; Poland: 3.01%; South Korea: 2.8%; Turkey: 1.71%; Colombia: 2.35%; Ireland: 3.98%; Singapore: 3.40%; Portugal: 4.83%; Thailand: 2.21%; Iran: 3.96%; Indonesia: 1.68%; Denmark: 3.78%; South Africa: 2.5%; Chile: 3.43%; Greece: 2.48%; New Zealand: 3.56%; Czech Republic: 3.08%; Taiwan: 1.81%; Phillippines: 2.74%; Romania: 3.52%; Malaysia: 2.04%; Hungary: 2.91%; Peru: 4.39%; Ukraine: 3.3%; Slovakia: 2.75%, Kazakhstan: 2.24%; Uruguay: 5.97%; Kenya: 2.71%; Viet Nam: 2.44%; Slovenia: 3.26%; Ecuador: 2.17%; Venezuela: 0.87%; Uzbekistan: 2.22%; Lithuania: 2.09%; Latvia: 3.72%; Estonia: 3.26%: Georgia: 4.13%; Paraguay: 1.68%; The former Yugoslav Republic off Macedonia: 4.12%; Kuwait: 1.45%; Malta: 3.41%; Mauritius: 3.36%; Caracao: 6.99%; Kyrgyzstan: 3.13%	-

Steenmeijer et al.	2022	The environmental impact of the Dutch health-care sector beyond climate change: an input–output analysis	Netherlands	17575 kt CO2eq	c.n.	7,30%	Scope 1 (Operational impacts (including anaesthetic gases)): 9,0%; Scope 2 (total): 11,1%, Scope 2 (Electricity): 10,5%, Scope 2 (Steam and hot water supply) 0,6%; Scope 3 (total): 79,9%, Scope 3(Coal & petroleum): 1,1%, Scope 3(Construction): 1,5%, Scope 3(Electrical, electronic &measuring equipment): 7,6%, Scope 3(Food, tobacco & agricultural products): 5,8%, Scope 3(Furniture & timber): 0,1%, Scope 3(General and special machinery): 1%, Scope 3(Metal products): 0,3%, Scope 3(Minerals & metals): 0,6%, Scope 3(Natural gas & gaseous fuels): 0,6%, Scope 3(Non-metallic mineral products): 0,3%, Scope 3(Paper products): 1,1%, Scope 3(Pharmaceuticals & chemical products): 41,2%), Scope 3(pMDI propellant releases): 0,4%, Scope 3(Private travel by patients & visitors (3,3%), Scope 3(Services): 6,7%, Scope 3(Textile): 0,4%, Scope 3(Transport):3,7%, Scope 3(Transport equipment): 0,1%, Scope 3(Waste management % disposal): 1,6%, Scope 3(Water distribution): 0,2%, Scope 3(Private travel by patients and visitors): 2%

Appendix: Method and transparency

Please use Ctrl + Scroll to zoom in this electronic appendix

Method	Demand Data source (detail)	Demand Data year	Number of demand/Expenditure categories	I-O table data source	I-O table data year	I-O model	Number of production sectors	Source of emission data/satelite account	Included Greenhouse Gases	Concardance matrix reported	Sensitivity/Uncertainty Analysis	Discussion of limitations
Top-Down	"National Medical Expenses Statistics"	2011	16	Ministry of internal Affairs and Communication	2011	SRIO (JIOT)	397	Japan National Report of GHGs Inventory (NRI)	CO2, CH4, N2O, HFCs, PFCs, SF6 and NF3	No	No	Yes
Top-Down	US National Health Expenditure Accounts	2003–2013	15	Federal Bureau of Economic Analysis	2002	SRIO	400+	EIOLCA	Equivalents	Yes	No	Yes
Top-Down	OECD: OECD health statistics database; China+India: World Bank health care expenditure	2014	OECD: 19	Eora	2014	MRIO (Eora)	14839	EDGAR	CO2	Available upon request	No	Yes
Top-Down	National Health Expenditures (NHEX) database maintained by the Canadian Institute for Health Information (CIHI)	2009-2015	13	(Statistics Canada)	2009	SRIO (Open IO-Canada)	112 sectors, 238 commodities	Statistics Canada Environmental Accounts and the Canadian National Pollutant Release Inventory	carbon dioxide, methane, and nitrous	Yes	No	Yes
Top-Down	Australian Institute of Health and Welfare (AIHW)	2015	16	Australian Bureau of Statistics	2014-2015	SRIO (Individually constructed)	360	Sydney University IELab	Equivalents	No	Monte-Carlo	Yes
Top-Down	national input–output table, China Health and Family Planning Statistics, China Construction Statistics, and China Science and Technology Statistics yearbooks	2013	8	National Bureau of Statistics of China	2012	SRIO	46	Climate Change Department of National Development and Reform Commission of the People's Republic of China. The People's Republic of China First Biennial Update Report on Climate Change	CO2, CH4, and N2O emissions	No	Monte-Carlo + Robustness (w/ onsite-emission in the medical institution sector) + Sensitivity (w/ energy intensities of floorspace of commercial buildings)	Yes
Hybrid	Scottish Government health expenditure	1990-2004	17	Scottish Government	1990-2004	SRIO (Scottish Government Input-Output tables)	123	UK National Statistics Environmental Accounts	CO2	Allocation without quantitative description	No	No
Hybrid	English Government	2004-2015	5	DEFRA	2004-2015	MRIO (UK-MRIO)	178	National Statistics Environmental Accounts	CO2 Beginning in 2010: CH4, N2O, HFCs, PFCs, SF6	Allocation without quantitative description	No	No
Top-Down	OECD health statistics database; World Health Organization, "Global Health Expenditure Database,"	2014	No	WIOD	2014	MRIO (WIOD)	2408	CO2: WIOD; Methane and Nitrous oxide: PRIMAP	carbon dioxide, methane and nitrous oxide gases	Reference to Pichler et al. (2019)	No	Yes
Top-Down	OECD Health Statistics 2017 supplied by the Austrian national statistical office	2014	9	Eora	2014	MRIO (Eora)	15909	EORA taken from EDGAR	CO2	Reference to Pichler et al. (2019)	No	Yes
Top-Down	Australian Institute of Health and Welfare	2016-2017	16	Australian Bureau of Statistics (ABS)	2017	SRIO (Individually constructed)	2880	No	No	No	No	Yes
Top-Down	National Health Expenditure Accounts of the Centers for Medicare and Medicaid Services (CMS)	2010-2018	16	Bureau of Economic Analysis	2012	SRIO (US Environmentally-Extended Input-Output model)	405	Inventory of U.S. Greenhouse Gas Emissions and Sinks	No	Yes	No	Yes
Hybrid	Public Expenditure Statistical Analysis Supply and Use tables from HM Treasury	1990-2019	19	DEFRA	1997-2016	MRIO (UK-MRIO)	424	UK MRIO	carbon dioxide [CO2], methane [CH4], nitrous oxide [N2O], and some categories of fluorinated gases/all Kyoto Protocol greenhouse gases	Yes	No	Yes
Top-Down	EORA	2000-2015	163	Eora	2000-2015	MRIO (Eora)	14838	EORA taken from EDGAR	carbon dioxide [CO2], methane, nitrous oxide, hydrofluorocarbon, chlorofluorocarb	No	Uncertainty	Yes
Hybrid	Centraal Bureau voo	2016	3	EXIOBASE	2016	MRIO (EXIOBASE)	7.987	EXIOBASE	CO2, CH4, N2O	Yes	No	Yes

Appendix: Transparency Score

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Author	**Year**	**Author (Year)**	**Title**	Health Care System	Total Carbon Footprint	tCO2/capita	% of total emission	Breakdown	Method	Demand Data source	Demand Data year	Number of demand/ Expenditure categories	I-O table data source	I-O table data year	Multiregionality of the model	Number of production sectors	Source of emission data/ satelite account	Included Greenhouse Gases	Concordance matrix reported	Sensitivity /Uncertainty Analysis	Discussion of limitations		
Nansai et al.	2020	Nansai et al. (2020)	Carbon footprint of Japanese health care services from 2011 to 2015	Japan	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	14	82,35%
Eckelman et al.	2016	Eckelman et al. (2016)	Environmental Impacts of the U.S. Health Care System and Effects on Public Health	USA	1	0	1	1	1	1	1	1	1	1	1	1	1	0,5	1	0	1	14,5	85,29%
Pichler et al.	2019	Pichler et al. (2019)	International comparison of health care carbon footprints	OECD countries; China; India	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	16	94,12%
Eckelman et al.	2018	Eckelman et al. (2018)	Life cycle environmental emissions and health damages from the Canadian healthcare system: An economic-environmental-epidemiological analysis	Canada	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	16	94,12%
Malik et al.	2018	Malik et al. (2018)	The carbon footprint of Australian health care	Australia	1	0	1	1	1	1	1	1	1	1	1	1	1	0,5	0	1	1	14,5	85,29%
Wu	2019	Wu (2019)	The carbon footprint of the Chinese health-care system: an environmentally extended input-output and structural path analysis study	China	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	16	94,12%
NHSScotland	2008	NHSScotland (2008)	National Health Service Scotland Carbon Footprint of NHS Scotland(1990-2004)	Scotland	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	13	76,47%
SDU series	2016	SDU series (2016)	Carbon update for the health and care sector in England 2015	NHS England	1	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	12	70,59%
HCH	2019	HCH (2019)	Health Care´s Climate Footprint	43 countries	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	15	88,24%

Weisz et al.	2020	Weisz et al. (2020)	Carbon emission trends and sustainability options in Austrian health care	Austria	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	16	94,12%
Malik et al.	2021	Malik et al. (2021)	Environmental impacts of Australia's largest health system	New South Wales, Australia	1	0	1	0	1	1	1	1	1	1	1	1	0	0	1	0	1	12	70,59%
Eckelman et al.	2020	Eckelman et al. (2020)	Health Care Pollution And Public Health Damage In The United States: An Update	USA	1	0	0	1	1	1	1	1	1	1	1	1	1	0	1	0	1	13	76,47%
Tennison et al.	2021	Tennison et al. (2021)	Health care's response to climate change: a carbon footprint assessment of the NHS in England	England	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	15	88,24%
Lenzen et al.	2020	Lenzen et al. (2020)	The environmental footprint of health care: a global assessment	189 countries	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	15	88,24%
Steenmeije	2022	Steenmeijer et al. (2022)		Netherland	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	15	88,24%
					15	7	12	13	15	15	15	14	15	15	15	15	1[illegible]	12	11	3	13		
					100,00%	46,67%	80,00%	86,67%	100,00%	100,00%	100,00%	93,33%	100,00%	100,00%	100,00%	100,00%	7[illegible],33%	80,00%	73,33%	20,00%	86,67%		

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Carbon footprint of healthcare systems: A systematic review of evidence and methods

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ABSTRACT

Objective: Given the demand for net-zero healthcare, the carbon footprint (CF) of healthcare systems has attracted increasing interest in research in recent years. This systematic review investigates the results and methodological transparency of CF calculations of healthcare systems. The methodological emphasis lies specifically on Input-Output based calculations.

Design**:** Systematic Review according to the PRISMA guideline.

Data sources: PubMed, Web of Science, EconBiz, Scopus, and Google Scholar were initally searched on November 25, 2019. Search updates in Pubmed and Web of Science were considered until December 2023. The search was complemented by reference tracking within all the included studies.

Eligibility Criteria: We included original studies that calculated and reported the CF of one or more healthcare systems. Studies were excluded if the specific systems were not named or no information on the calculation method was provided.

Data extraction and synthesis: Within the initial search, two independent reviewers searched, screened, and extracted information from the included studies. A checklist was developed to extract information on results and methodology and assess the included studies' transparency.

Results: 15 studies were included. The mean ratio of healthcare system emissions to total national emissions was 4.9% [minimum 1.5%; maximum 9.8%], and CFs were growing in most countries. Hospital care led to the largest relative share of the total CF. At least 71% of the methodological items were reported by each study.

Conclusions: The results of this review show that healthcare systems contribute substantially to national carbon emissions, and hospitals are one of the main contributors in this regard. They also show that mitigation measures can help reduce emissions over time. The checklist developed here can serve as a reference point to help make methodological decisions in future research reports as well as report homogeneous results.

Keywords: life-cycle assessment, input-output, global warming potential, healthcare

STRENGTHS AND LIMITATIONS OF THE STUDY

- The assessment of methodological choices and the transparency of methods when assessing the greenhouse gas emissions of entire sectors in systematic reviews can help deepen our understanding of the results.
- The systematic review of all available evidence on greenhouse gas emissions of and within healthcare can help to understand its impact and to identify reduction potentials.
- This review was limited to articles in English and German, and excluded assessments, grey literature from public reports, and reports from statistical offices published in other languages.

INTRODUCTION

Background

Climate change is one of the most pressing issues of our time[1]. Considering the correlation between the gross domestic product (GDP) and carbon emissions[2], the healthcare industry is likely an essential contributor to greenhouse gas (GHG) emissions. Demographic shifts and income effects have likely spurred greater demand for healthcare services, a trend projected to persist and further elevate the economic significance of the healthcare industry[3]. Evidence on healthcare's GHG emissions is needed to understand its role better.

Methods for calculating a carbon footprint (CF) can be broadly categorized into bottom-up and top-down approaches. Bottom-up methods, such as process-based lifecycle assessments (LCA), require extensive data, which currently limits their application at a sectoral level. However, the CF of various sectors can be estimated using a more uncertain top-down-methodology, providing a trade-off for broader coverage. In this case, emissions are divided according to the final demand or economic sectors of emission occurrence.

Input–output (I–O) analysis, which follows this approach, can be used to estimate sectoral CF[4]. Calculations of the CF use the static open-quantity I–O model in combination with an environmental extension. They rely on two fundamental building blocks: an I–O table and a demand vector. The I–O table describes the interactions between the sectors of production, often in monetary terms, and are usually constructed by national statistics offices. With additional information on their environmental impact, the emission intensity of a sector and its upstream production processes can be calculated. The demand vector represents the expenditures of the relevant sectors. For example, the demand vector of the healthcare sector includes expenditure on diesel fuel to power ambulances, electricity consumed by hospitals, and all other forms of energy. It may be necessary to synchronize the structures of the I–O table and the demand vector by balancing the definitions of different sectors and adjusting the level of sectoral aggregation.

I–O models can be grouped into single-region I–O (SRIO) and multi-region I–O (MRIO) models. SRIO models utilize I-O data from a single country, thus restricting their scope to domestic production and emissions only. MRIO models connect multiple I–O tables from multiple countries, and can thus account for different levels of production and "trade" in emissions (i.e., emissions occurring in one country related to the final demand of another country). The need for synchronized data from multiple countries complicates the development and update of the data of MRIO models.

The results of CF calculations for a specific sector can be influenced by methodological choices, including the selection between SRIO or MRIO models and the GHGs taken into account. Therefore, comprehensive reporting is needed to ensure the transparency of methodological choices, the data, and the results. However, our search of the literature yielded neither a standardized procedure nor standardized reporting.

Objective

The aim of this study is to conduct a systematic review of research utilizing I-O analysis to quantify the CF of systems, encompassing total CF, CF per capita, and its proportion relative to the national CF. Furthermore, data on emission trends over time, can deepen the understanding of the trajectory of the CF of healthcare systems. Finally, an assessment of the methodological choices and their transparency within the reviewed studies can help to discuss the state of the methodology and provides a foundation to discuss methodological differences between the studies.

METHODS

Search strategy and selection criteria

This systematic review was performed by following the PRISMA guidelines[5] (the checklist is provided in the supplementary file 1). The databases PubMed, Web of Science, EconBiz, Scopus, and Google Scholar were searched for studies on November 25, 2019. The full search strategy is provided in supplementary file 2. The search was complemented by reference tracking within all the included studies. The updated search considered hits in Pubmed and Web of Science up to December 2023.

Following the screening of the titles and abstracts, studies were included for further investigation if they had (i) addressed the method of CF calculation (ii) addressed one or more healthcare systems or subsystems, and (iii) been written in English or German. A healthcare system was defined as the national healthcare system, federal system, and/or state system. Single entities, such as individual hospitals, and specialized branches, such as dentistry, were excluded. In addition to the criteria used for screening the titles and abstracts of articles, full-text articles were excluded if they (i) did not name the specific healthcare (sub)system, (ii) did not calculate the CF, or (iii) did not provide any information on the method of calculation used. In the initial search, two of the authors separately screened titles and abstracts, read the full text, extracted data and assessed the transparency. In the case of disagreement, decisions were made through discussion until a consensus was reached. During the search update these steps were conducted by one person.

Data extraction and analysis

The CF per capita, the contribution of healthcare to the country's total CF emissions, and the origins of emissions were used as main results of the studies. The breakdown of the emission sources could be in scopes, demand categories, or places of origin. The Greenhouse Gas Protocol Corporate Accounting and Reporting Standard[6] proposes three standardized scopes. Scope 1 represents direct emissions from owned or controlled sources, Scope 2 represents indirect emissions generated by the purchased energy, and Scope 3 represents all indirect emissions that occur in the value chain. The categories of demand included the classes of expenditures of the demand vector, and the places of the origin of emissions were divided into hospitals, ambulatory services, and so on.

In addition to evaluating their general characteristics and results, we developed and applied a checklist to assess the methodological transparency of the studies under consideration. We opted to use the term 'transparency' rather than 'quality' to address the issue that even a flawless study could receive a low score if the authors failed to adequately report their methodology. The checklist served as both a qualitative extraction tool and a quantitative transparency tool. The qualitative extraction tool facilitated the assessment of information from each included study, with responses to each criterion collected accordingly. As a quantitative transparency tool, it was evaluated whether the criteria were adequately addressed. When information was provided, the criterion was considered fulfilled, resulting in an increase in the transparency score. All criteria were weighted equally, therefore for each "fulfilled" criterion one point was added to the transparency score, with a maximum of 17 points per study.

The utilization of I-O data can introduce uncertainties into the assessment, given that the top-down approach relies on aggregated information from industrial sectors. When heterogeneous products with varying emission intensities are grouped into one industry, aggregation errors might occur: the average emission intensity of the aggregated industry would not appropriately reflect the emissions caused by the specific product within the industry[7]. Therefore, information on the extend of usage of I-O method (criterion 5), and the number of industry sectors (criterion 12) could help to understand the scope of this uncertainty.

The choice between MRIO and SRIO (criterion 11) can also help to understand the level of uncertainty. While MRIOs can account for differences between countries and trade between these countries, SRIO might provide a more detailed framework of the domestic economy. Finally, the specific source of the I-O tables (criterion 9) and emission data (criterion 13) can help the reader to assess the quality of the used data.

Similar to the I-O data, the level of aggregation within the demand data can impact the accuracy of the results. The number of demand or expenditure categories (criterion 8) can indicate on the level of aggregation and the source of demand data (criterion 6) could help to assess the quality of the data source. The quality of the outcomes is also influenced by the alignment between the temporal representativeness of the demand data (criterion 7) and the I-O data (criterion 10). Changes over time (e.g. in technology, import and exports) can impact the results and in the best case both data sources refer to the same year. Finally, information on the matching process of demand categories and industry sectors, the publication of the concordance matrix (criterion 15), increases transparency for the reader.

The quantitative (criterion 16) and qualitative (criterion 17) assessment of uncertainty helps the readers to contextualize the results. A list of the included GHGs can indicate the scope of the study, in this case 0.5 were given, when the unit (typically CO_2equivalents (CO_2eq)) was mentioned and another 0.5 points if all included GHGs were listed. For the final transparency checklist, the criteria on outcomes (table 1a) and on methodology (table 1b) were combined. A more detailed description of the transparency criteria are provided in the supplementary file 3.

Table 1a: Extracted outcomes

	Number	Criterion
System description and outcomes	0 *	System description
	0 *	Years for which total emissions are reported
	1	Total carbon footprint
	2	Carbon footprint as a share of the total national CF
	3	CF per capita
** not included in the transparency score*		

Table 1b: Extracted methodological items

Method	5	LCA method
	6	Source of demand data (detail)
	7	Year of demand data
	8	Number of categories of demand or expenditure
	9	Data source of I–O table
	10	Year of I–O table
	11	Multi-regionality of the model
	12	Number of production sectors
	13	Source of emission data
	14	GHGs considered
	15	Concordance matrix reported
	16	Sensitivity and uncertainty analysis
	17	Discussion of limitations

Emissions over time

To assess trends in GHG emissions of healthcare, data from all studies that reported total emissions for more than one year were taken. The data were normalized to the respective starting point of the report as a base year. Therefore, GHG emissions of time period t were divided by the GHG emissions of the base year t_0 and used in a descriptive analysis.

Patient and public involvement

None

RESULTS

A total of 4,285 records were identified in the three searches (figure 1). After removing duplicates and searching for eligible title, abstracts, and full texts, 15 reports were included in this review (figure 1). A summary of included studies is provided in Table 2. The detailed results of the data collection are listed in the supplementary file 4 and 5

-Insert figure 1 around here-

Characteristics of the studies considered

Eleven studies focused on a single national healthcare system, including England [8 9], Japan [10], USA [11 12], Canada [13], Scotland [14], China [15], Australia [16], Austria [17], and the Netherlands[18]. The series of CFs from the Sustainable Development Unit of the English NHS was aggregated, and only the newest available report was cited. One study examined the healthcare system of the largest Australian state, New South Wales [19], while three studies reported on healthcare systems in multiple countries. Pichler et al. [20] reported results for 36 countries, Healthcare without Harm (HCH) for 43 countries [21], and the investigation by Lenzen et al. [22] considered 189 countries.

Excluding the one that assessed the Scottish NHS, all studies were published after 2016. However, it's worth noting that the year of the analysis could be older. For instance, the study by Nansai et al. [10] was published in 2020 but utilized demand data from 2011.

Table 2: Characteristics and main results of the studies considered in this review; CF: carbon footprint, Mt: megatonnes CO2eq: CO2 equivalents, t: tonnes, cap: capita

Author (Year)	Healthcare system	Years total emissions reported	Latest year of emissions reported	CF in Mt CO_2eq	% of total national CF	tCO2eq/cap	Transparency score
Tennison et al. [8]	England	1990-2019	2019	25	n.i.	0,445	88%
SDU [9]	England	1992-2017	2017	25	n.i.	n.i.	71%
Nansai et al. [10]	Japan	2011-2015	2015	72	4,6	0,49	82%
Eckelman and Sherman [11]	USA	2003-2013	2013	655	9,8	2,07	85%
Eckelman et al. [12]	USA	2010-2018	2018	554	n.i.	n.i.	76%
Eckelman et al. [13]	Canada	2009-2015	2015	33	5,7	0,92	94%
Health Facilities Scotland [14]	Scotland	1990-2004	2004	2,6	3,6	0,52	76%
Wu [15]	China	2012	2012	315	2,7	0,23	94%
Malik et al. [16]	Australia	2013-2015	2015	36	7,0	1,50	85%
Weisz et al. [17]	Austria	2014	2014	6,8	7	0,8	94%
Steenmeijer et al. [18]	Netherlands	2016	2016	17,575	17,6	n.i.	88%
Malik et al. [19]	New South Wales, Australia	2017	2017	0,008	6,6	n.i.	71%
Pichler et al. [20]	OECD countries; China, India	2014	2014	s. supplementary file 4	Ø 5,5 s. supplementary file 4	supplementary file 4	94%
Karliner et al. [21]	43 countries; EU; rest of the world	2014	2014	supplementary file 4	Ø 4,4s. supplementary file 4	supplementary file 4	88%
Lenzen et al. [22]	Global	2007-2015	2015	2 290	n.i.	n.i.	88%
* n.i.= not identified							

Differences in methodology and data

Eleven studies considered top-down data on emissions, while three studies employed bottom-up data on energy usage [8 9 14]. Steenmeijer et al. [18] incorporated bottom-up data regarding the quantities of anesthetic gases, inhalers and travel.

Most single-country studies used SRIO data from the respective governmental offices. In contrast, the studies on British and Dutch healthcare, and those that considered more than one country, used MRIO data. Additionally, Malik et al. [23] used MRIO data, however, the database only included data from Australian regions. The EORA database emerged as the most frequently utilized MRIO database (three times), with one study each employing the WIOD database, the EXIOBASE database, and the MRIO database provided by the British Department for the Environment, Food, & Rural Affairs.

The number of production sectors varied among the SRIO studies, ranging from 46 to 405 sectors. The MRIO studies typically utilized more extensive databases comprising approximately 15,000 sectors, although the MRIO study focusing on the UK considered 424 sectors.

All studies considered CO_2 emissions. However, only five studies considered the six GHGs covered in the Kyoto Protocol; three studies considered CO2, methane, and nitrous oxide; two reported only that they had used CO2eq as unit; and two studies did not report any included GHG or the unit in which the outcomes were reported. The data on emissions were drawn mostly from national accounts in the case of SRIO databases and integrated accounts in the case of MRIO databases. One study did not report the source of its emission account data.

The demand data was taken either from official health expenditure accounts or from international organizations such as the WHO and the World Bank (which uses data provided by national offices and accounts). Lenzen et al. [22] identified and directly used data on healthcare-related sectors from the MRIO database EORA. The number of reported expenditure accounts varied, mostly ranging from 13 to 19, although three studies reported fewer accounts. Weisz et al. [17] utilized nine accounts, Wu [15] used eight accounts, and the study on the NHS in England employed five accounts [9]. Due to the distinct methodologies employed by Lenzen et al. [22] and the structure of the EORA database, which reports country-specific sectors, they utilized 163 sectors from the EORA as demand data.

The time periods covered by the demand data were largely consistent with those covered by the respective I-O data. Some studies reporting outcomes for more than one year only used one reference year for the I-O database and adjusted the demand data for inflation. [11-13]. The lag between the time at which the data were collected and the time of publication of the corresponding study ranged from three to six years, with deviations in the studies by Nansai et al. [10] Eckelman et al. [12] (two years) and in the report by the SDU [9]. The latter reported the CF periodically; the lag between the latest publication and the latest data was one year [9]. Further information on this is provided in the supplementary file 5.

Five studies provided their concordance matrices, which link the categories of demand with the industrial sectors. The authors of one study had made their matrix available upon request, and two articles had referred to a matrix previously used in another study. Five studies did not report their concordance matrices.

Reporting of the results

The origins of emissions were documented six times in the three scopes defined by the GHG protocol. Emission sources were reported eight times in the (sub)categories of final demand, such as hospitals or pharmaceuticals. Two studies reported the economic sector in which the emissions occurred, e.g., the textile sector or the manufacture of fuels. Furthermore, three studies reported a breakdown of emissions by employing more than one reporting structure. Several differences were observed in the scopes of the reported results. Some studies directly referenced the GHG protocol while others reported emissions in divisions, such as travel, energy, procurement, etc. 47% of the articles did not normalize the results by reporting the CF per capita.

Overall transparency

Except for the three criteria "reporting of the concordance matrix", "uncertainty analysis", and "CF per capita", all criteria were fulfilled by at least 75% of the studies (Figure 2). The studies fulfilled between 70.5% and 94% of all criteria with a mean of 85% (Figure 3). The full transparency assessment is provided in supplementary file 6.

-Insert figure 2 around here-

-Insert figure 3 around here-

OUTCOMES

Emissions over time

The results of the time series revealed successful efforts to mitigate the CF by the NHS in England and Scotland (Figure 4). In the nearly three decades from 1990 to 2019, the English NHS reduced its CF by roughly 25%. The four remaining countries (Japan, Canada, USA, and Australia) examined in the studies considered here and the global trend showed increased CF due to healthcare (Figure 4). The annual increase in the CF ranged from 0.7% (USA, 2010–2018) to 3.8% (Japan, 2011–2015) over the observed period, with the CFs of Canada (1.9%, 2009–2015), USA (2.8%, 2011–2015), and Australia (2.9%. 2013–2015) in between these extremes. The global trend showed an increase in the CF of 2.7% per year from 2000 to 2015.

-Insert figure 4 around here-

Breakdown

The emission sources were mainly reported using the scope system from the GHG protocol or the categories of expenditure, i.e., the categories of final demand. The largest dataset that used the categories of final demand was provided by Pichler et al. [20], who applied this to 36 countries and reported the average values. Medical retail (i.e., provider of healthcare products without medical services, e.g., pharmacies), hospitals, and ambulatory healthcare services constituted 80% of the CF of healthcare, with medical retail contributing 33.1%, hospitals

28.6%, and ambulatory healthcare services 18%. They also made a major contribution to the CF in Japan (hospitals, 25.1%; ambulatory services, 22.7%) , USA in 2013 (hospital care, 36%; physician and clinical services, 12%) [11] and in 2018 (hospital care, 34.9%; physician and clinical services, 12.6%; ambulatory medical services, 4.8%) [13], Australia (public hospitals, 34.4%; private hospitals, 10.2%; ambulatory medical services, 15%) [16], China (public hospitals, 47%; private hospitals, 4%) [15], and Austria (hospitals, 32%; ambulatory services, 18%) [17]. Other important categories of emissions were construction and pharmaceutical products, at around 10% [11 16 20], with a higher share in China (pharmaceuticals, 18%; construction, 15%) [15].

An alternative approach involved categorizing emissions into direct emissions, indirect emissions through electricity production, and other indirect emissions. This division along these lines could also align with the three GHG protocol scopes.

By averaging data from 43 countries, HCWH reported a distribution of 17% for scope 1 emissions, 12% for scope 2 emissions, and 71% for scope 3 emissions [21]. These findings, particularly the significance of scope 3 emissions, are corroborated by evidence from single-country studies. [8 11 12 14 24]. The scope 3 emissions were further divided into those due to travel (patient and visitor travel, and staff commutes), production of pharmaceuticals, and medical instruments and equipment, which accounted for the largest share of scope 3 emissions.

Scotland's scope 3 travel emissions in 2004 were 18% while those of England accounted for 13% in 2015 and 9.6% in 2018 [9]. The share of emissions owing to pharmaceutical production ranged from 11% and 18%, and that owing to medical instruments and equipment accounted for 7%–10% of the total CF [13 14 24].

The ratio of emissions by the healthcare sector to the total CF in studies focused on a single country ranged from 2.7% in China in 2012 [15] to 9.8% in the USA in 2013 [11]. The three cross-national studies considered here estimated that healthcare had contributed 5.5% [20] on average to the national CF in 2014 and 4.4% in 2015 [22].

DISCUSSION

Interpretation of results

The results indicate that healthcare significantly contributes to the CF, both in absolute numbers and in relation to a country's overall emissions and its per capita emissions. However, the results varied among the studies, and their calculation methods were heterogeneous and frequently not fully transparent. The breakdown of the sources of emissions revealed the major contribution made by hospitals.

The time series results showed that the trend of emissions due to healthcare was positive in all the countries considered, i.e., they were increasing, except in Scotland and England. These results align with the graphical results provided by Lenzen et al. [22]. Furthermore, they indicated that the efforts of the British NHS systems to reduce their carbon footprint based on the Greener NHS program was effective in reducing GHG emissions. The breakdown of the sources of emissions verified the important contribution of hospitals. However, hospitals provide the majority of medical care in many countries. Therefore, their large CF is not surprising but might motivate the relevant decision-makers to allocate scarce resources more efficiently. The breakdown further showed that a large portion of the CF of healthcare stemmed from scope 3 emissions. Decision-makers may conclude that the most considerable reduction in emissions can be obtained by considering staff and patient travel. Therefore, "greening" the healthcare sector requires a sustainable transportation system and green healthcare goods.

Most data were from the OECD countries, China, and India. The only exception was the work by Lenzen et al. [22], who considered 189 countries in their analysis [22]. However, even if the distribution of countries limits the representativeness of the results, the findings are consistent with the fact that OECD countries are the main emitters of GHGs.

While heterogeneity in methodology, in general, can lead to more robust results and a more informative perspective on the issue at hand, the differences in I–O methodologies to calculate the CF of healthcare may reduce the comparability of the results. However, the choice of method depends on the corresponding research question, for example, while SRIO may be more up to date and include a more detailed description of the domestic production sectors, MRIO can account for international trade and differences in production emissions between countries.

Limitations

This review has several limitations. First, the review process used here was limited due to restrictions on the language used in the study and those related to access. Second, it is possible that further CF assessments exist which were published in the official languages of many countries in the grey literature, such as publications by national statistics offices or governmental agencies. Because this review included only publications in English and German, many such studies have likely been neglected. Third, the reporting scheme and transparency score used in this study may have limitations. Both were based only on a consensus among the authors. The instruments used to assess the quality of the published studies are typically chosen based on a broad consensus among experts, such as in the case of the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) [25]. However, we did not find similar guidance for I–O analyses. Finally, the review is limited as the studies only report averages instead of confidence intervals (CI) or data ranges. Only Malik et al. [16] report the 68% CI with a range of 20,748 kt CO2eq in the results (68% CI 25,398kt CO2eq –46,146 kt CO2eq). Therefore, the results presented in both the individual studies and in this review should not be regarded as precise measurements, but rather as indicative trends or directions.

Implications for further research

This review identified research gaps that should be investigated by future research. First, there is a need to assess the potential effects of efforts to reduce emissions on the system and pathways to a low-carbon healthcare system. Second, it should be examined errors of aggregation when using the I–O methodology in the healthcare context. Third, the differences in the outcomes when making different methodological choices (SRIO or MRIO, systemic boundaries, etc.) should be analyzed to guide future research.

The transparency checklist used in this study can serve as an initial reference point for future developments. For example, in the checklist's current state, all criteria are weighted equally. However, some might be less crucial to delivering harmonized study findings. An extended consensus process with further experts is proposed to validate the checklist further and increase its value for research and practice.

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DECLARATIONS

Author contributors

Mattis Keil: Methodology, Screening, Formal Analysis, Writing – Original Draft, Writing-Review and Editing, Visualization; **Leonie Frehse:** Methodology, Screening, Formal Analysis, Writing – Original Draft; **Marco Hagemeister:** Methodology, Screening, Formal Analysis, Writing – Original Draft **Mona Knieß:** Methodology, Screening, Formal Analysis, Writing – Original Draft **Oliver Lange:** Conceptualization, Methodology, Writing - Review and Editing**, Tobias Kronenberg:** Methodology, Writing – Review and Editing **Wolf Rogowski:** Conceptualizing, Methodology, Writing - Review and Editing, Supervision, Project administration. All authors have read and approved the final manuscript for publication.

Conflict of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data statement

The data that support the findings of this study are available in supplementary file 4 "System description and results" and supplementary file 5 "Methods and transparency." Further data are available from the corresponding author, [MK], upon reasonable request.

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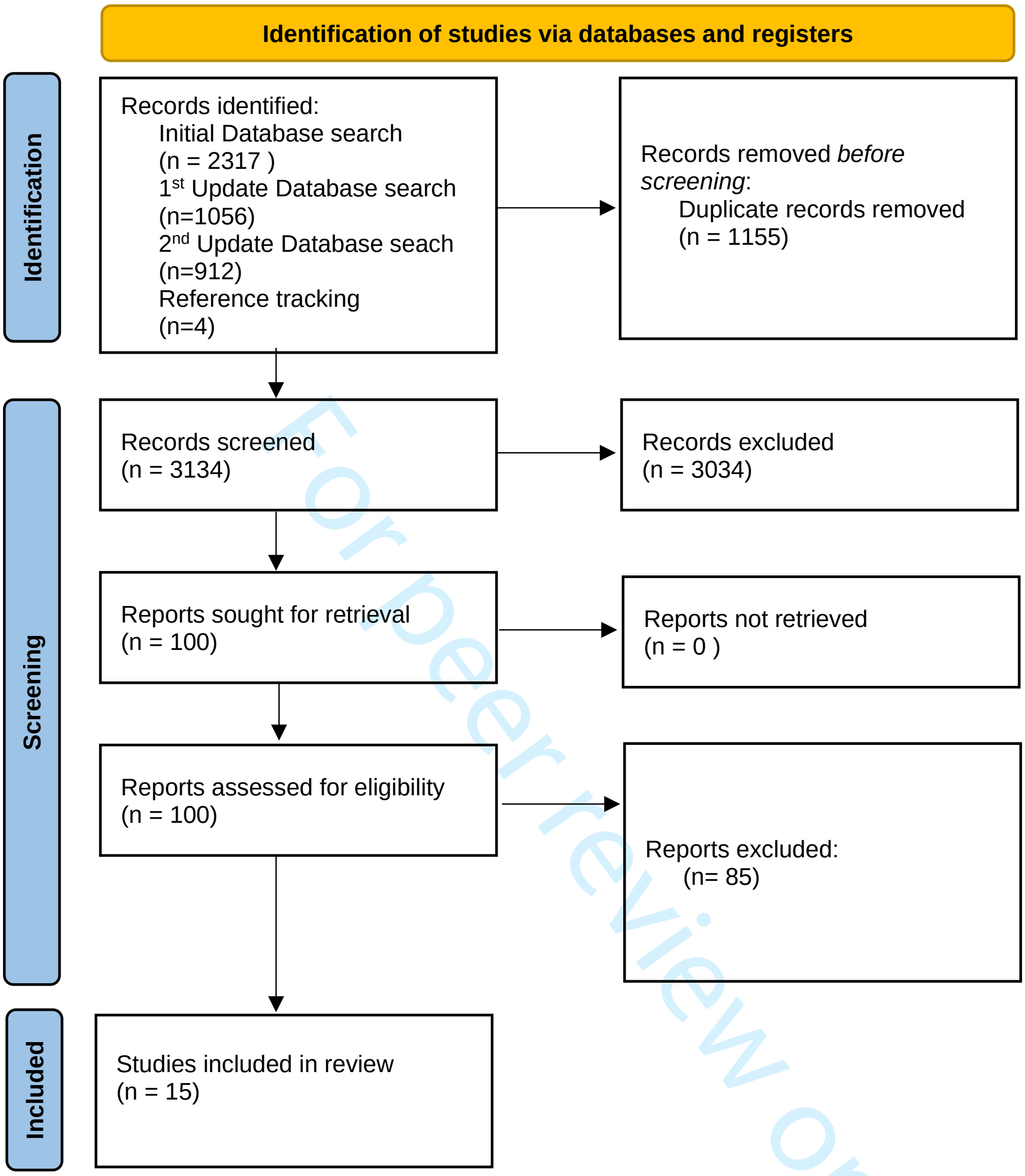
Figure legends/captions

Figure 1: Prisma Flow Diagram, based on Page et al. (2021)

Figure 2: Fulfilment rate of the transparency and reporting criteria

Figure 3: Transparency score in % per article

Figure 4: Emission trends over time



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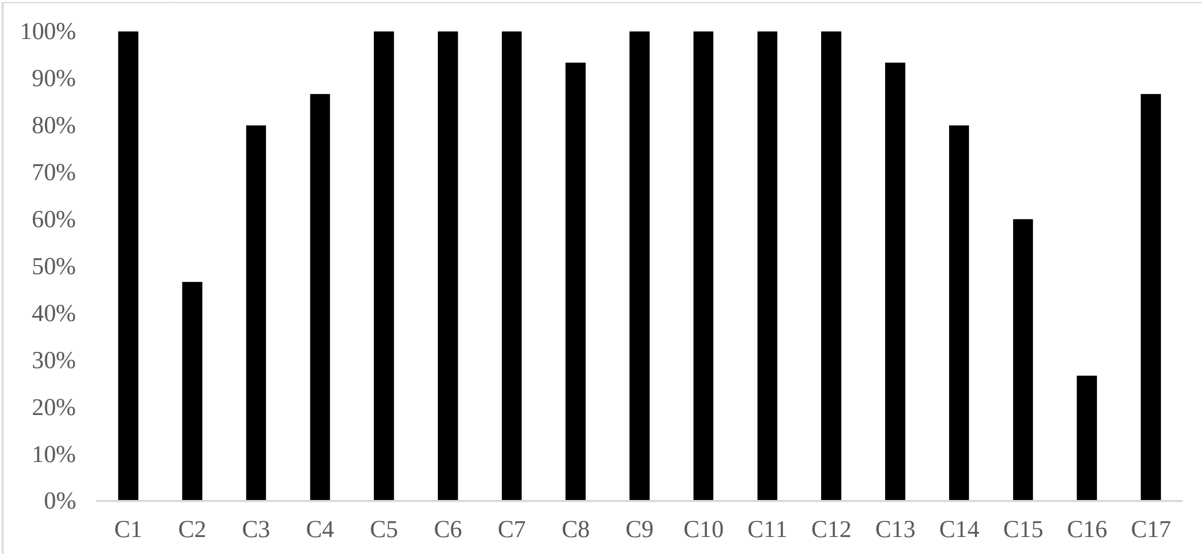

Figure 2: Fulfilment rate of the transparency and reporting criteria

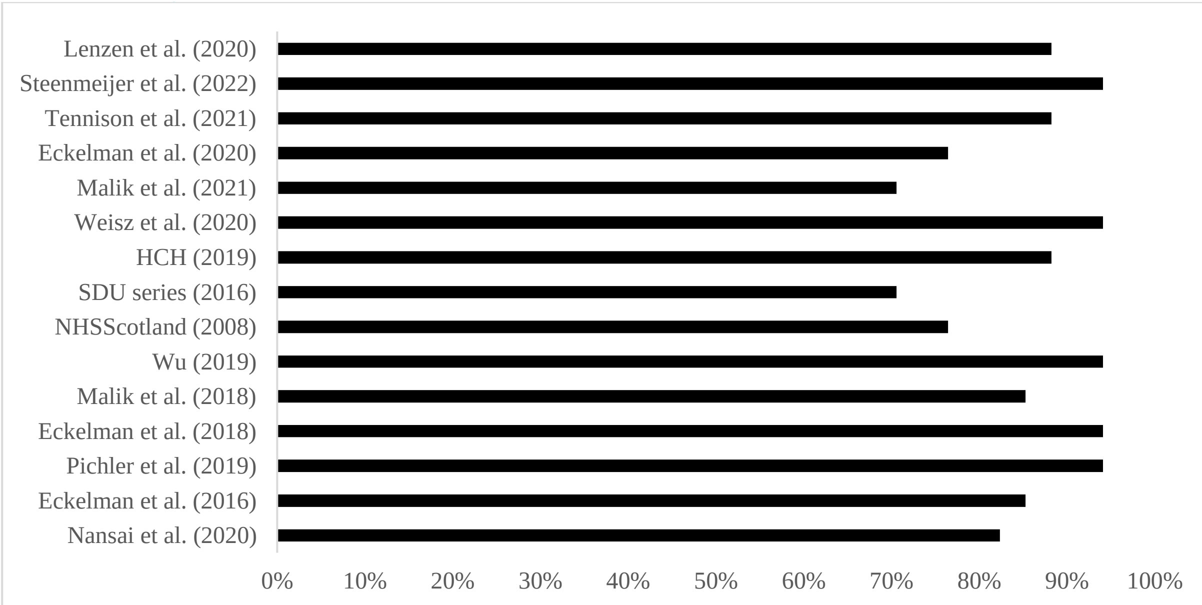

Figure 3: Transparency score in % per article

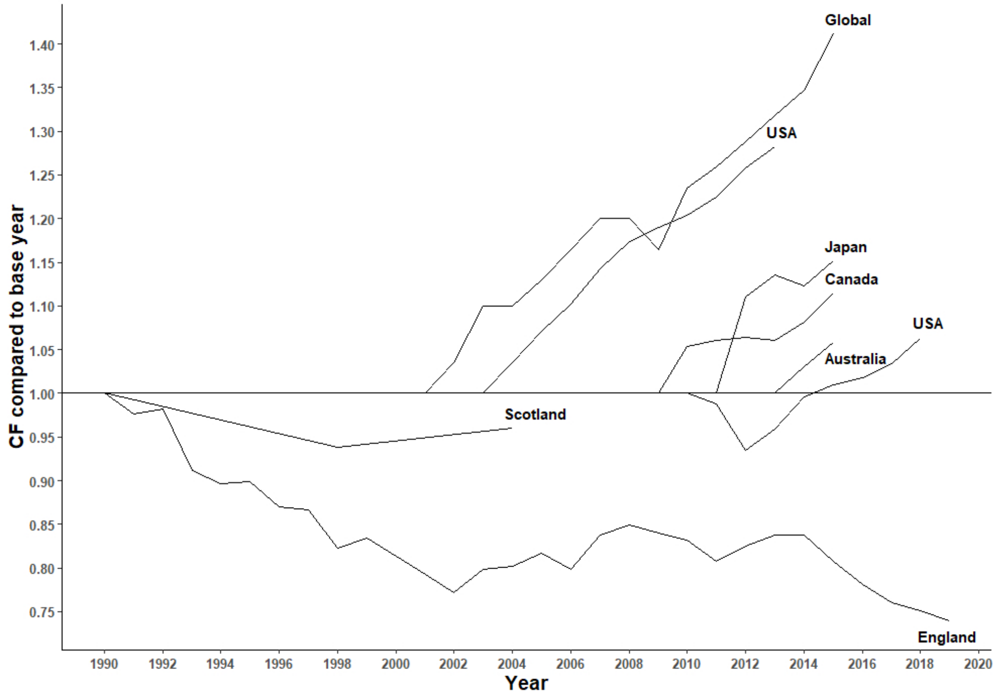

Figure 4: Emission trends over time

83x59mm (300 x 300 DPI)

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Title, Methods
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page 1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Introduction on Page 3
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Introduction on Page 3
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Methods section on Page 4
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Methods section on Pages 3-4
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Supplementary materials
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Methods section on Page 4
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Methods section on Page 4
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Methods section on Pages 4-5
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Methods section on Pages 4-5
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	n.a.
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Methods section on Page 4
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	n.a.
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	n.a.

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	n.a
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	n.a.
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	n.a.
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	n.a
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	n.a.
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	n.a
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Results on page 5
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	n.a.
Study characteristics	17	Cite each included study and present its characteristics.	Results on pages 5-6
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	n.a.
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Results on pages 6-7
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	n.a.
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	n.a.
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	n.a.
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	n.a.
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	n.a.
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	n.a.
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Discussion on page 8
	23b	Discuss any limitations of the evidence included in the review.	Discussion on page 8
	23c	Discuss any limitations of the review processes used.	Discussion on page 8
	23d	Discuss implications of the results for practice, policy, and future research.	Discussion on page 9
OTHER INFORMATION			

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Page 9
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Page 9
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	n.a.
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Page 10
Competing interests	26	Declare any competing interests of review authors.	Page 10
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Appendix

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

For more information, visit: http://www.prisma-statement.org/

Full search strategies for all databases

DATABASE	SEARCH TERM
SCOPUS	TITLE-ABS(((footprint OR "carbon emission" OR "greenhouse gas*")) AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR “health services”))) OR ("input-output" AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR “health services”)) AND ((footprint OR "carbon emission" OR "greenhouse gas*" OR environmental* extended))) AND NOT DOCTYPE(ed) AND NOT DOCTYPE(er) AND NOT DOCTYPE(le) AND NOT DOCTYPE(no) AND NOT DOCTYPE(pr)
WEB OF SCIENCE	TOPIC: ((((footprint OR "carbon emission" OR "greenhouse gas*")) AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR “health services”))) OR ("input-output" AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR “health services”)) AND ((footprint OR "carbon emission" OR "greenhouse gas*" OR environmental* extended))))Timespan: All years. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC.
ECONBIZ	(((footprint OR "carbon emission" OR "greenhouse gas*")) AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR “health services”))) OR ("input-output" AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR “health services”)) AND ((footprint OR "carbon emission" OR "greenhouse gas*" OR environmental* extended)))
PUBMED	Search (((footprint OR "carbon emission" OR "greenhouse gas*")) AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR “health services”))) OR ("input-output" AND (("health care" OR "healthcare" OR "health-care" OR "health sector" OR "health system" OR “health services”)) AND ((footprint OR "carbon emission" OR "greenhouse gas*" OR environmental* extended)))

S1: Further description of the transparency criteria

#	Criteria	Further description
System description and results		
0 (not included in the transparency score)	System description	It should be reported which national healthcare system was assessed. Healthcare system was defined, closely to the definition of the WHO as follows: *"A health system consists of organizations, people and actions whose primary intent is to promote, restore or maintain health."*
1	Total Carbon Footprint	The total CF of a healthcare system can help to understand the total impact the system has on climate change
2	Carbon Footprint as a share of the total national CF	The share of healthcare's CF of the total national CF can help to understand the importance of the healthcare system to mitigate the climate impact of a country as well as to analyze systematic differences in the importance of the healthcare systems in mitigating the national CF between countries
3	CF per capita	The CF per capita can help to compare healthcare systems between different-sized countries.
4	CF breakdown	The division of total CFs in scopes or subcategories can help to understand the "hot spots" in GHG emissions within healthcare systems.
Method and Transparency		
5	LCA method	The LCA method can be distinguished between Top-Down (i.e. Using only Input-Output Data), Bottom-Up (i.e. using only Process-based data), and Hybrid (Using both data types). Each type has its advantages and disadvantages and should be reported to enable a first assessment of the used method.
6	Demand Date source (detail)	To avoid inaccurate, outdated, or unfitting data the data source is important to report for transparency.
7	Demand Data year	To avoid inaccurate, outdated, or unfitting data the data year is important to report for transparency.
8	Number of demand or expenditure categories	The number of demand or expenditure categories can help to assess the level of detail in which the healthcare system is modeled. The more expenditure categories are used, the higher the level of detail might be.
9	I-O table data source	Similar to the demand vector, the data source of the I-O table is important to ensure the data quality and transparency
10	I-O table year	Similar to the demand vector the data year of the I-O table is of importance to ensure the data quality and transparency
11	Multiregionality of the model	I-O tables can be distinguished in SRIO, which aggregates the economic sectors of a single country, or MRIO, which aggregates the sectors of multiple countries. As each of the models has its implications it is important to report the model type.
12	Number of production sectors	The number of production sectors within the I-O model can help to estimate the level of aggregation. The more production sectors are used the less aggregated the model might be.

13	Source of emission data	The report of emissions data sources ensures the quality.
14	Included GHGs	The results might vary dependent on the included GHGs with more included GHG leading to a higher CF. This leaves room for biases and reduced comparability between the studies. A list of the included GHGs and the used unit for the results can help to identify differences between the studies and contextualizes the results.
15	Concordance matrix reported	The bridge matrix connects the demand vector with the IO table. Each value in the demand vector, representing a demand from a certain economic sector, has to be connected to one or multiple sectors within the IO table. The bridge matrix defines these connections and makes the connection operationalizable. The bridge matrix can be either presented in matrix form or as a table classifying the demand vector values to IO table sectors.
16	Sensitivity and Uncertainty analysis	Quantitative analysis of uncertainty can add clarity and transparency to uncertainty reporting to the reader. Furthermore, it can help prioritize efforts to improve data quality in those areas of uncertainty which contribute most to the overall uncertainty of the results
17	Discussion of limitations	A variety of limitations can arise from CF calculations with IO models (e.g. insufficient data, high level of aggregation, etc.). Therefore, a critical discussion of limitations can increase transparency.

Appendix: System description and results

Please use Ctrl + Scroll to zoom in this electronic appendix

Author	Year	Title	Health Care System	Carbon Footprint	tCO2/capita	% of total emission	Breakdown
Nansai et al.	2020	Carbon footprint of Japanese health care services from 2011 to 2015	Japan	2011:62.5mt CO2 equivalent; 2012: 69,4mt CO2eq; 2013: 71 mt CO2eq; 2014 70.2mt CO2eq; 2015 72 mtCO2eq	c.n.	4,6% of the total domestic GHG emission	~Capital vs. Service: Service:86%; Capital formation 14% ~Broad Categories: Fixed Capital Formation: 15.92%; Nursing services 16.16%; Health and Hygiene : 1.3% ; Household medication; 2,4% ; Medical services 66,4% ~Detailed Categories: Medical services (hospitalization): 25.12%; Medical services (non-hospitalization): 22,72%; Medical services (pharmacy dispensing) 13.1%; Home medication: 1.84%; Nursing care (facility services) 6.64% ; Nursing care (excluding facility services): 9,47%; Private fixed capital formation for medical services 10,22%; Private fixed capital formation for nursing care 1.62%
Eckelman et al.	2016	Environmental Impacts of the U.S. Health Care System and Effects on Public Health	USA	2003:511 Mt CO2eq; 2004:529 Mt CO2eq; 2005:547 Mt CO2eq; 2006:563 Mt CO2eq; 2007:584 Mt CO2eq; 2008:600 Mt CO2eq; 2009: 608 Mt CO2eq; 2010:615 Mt CO2eq; 2011:626 Mt CO2eq; 2012:643 Mt CO2eq; 2013:655 Mt CO2eq	c.n.	2003: 7,2%; 2004: 7,3%; 2005: 7,6%; 2006: 7,8%; 2007: 8,0%; 2008: 8,5%; 2009: 9,2%; 2010: 9,0%; 2011: 9,3%; 2012: 9,9%; 2013: 9,8%;	Hospital Care: 36%; Physicians and Clinical Services: 12%; Prescription Drugs: 10%; Other Professional Services: 1,5%; Dental Services:1,6%; Other Health, Residential, Personal Care: 3,8%; Home Health Care: 2,5%; Nursing Care Facilities and Continuing Care Retirement Communities: 6%; Durable Medical Equipment: 2,6%; Other Non-Durable Medical Products: 2,2%; Government Administration: 2,2%; Net Cost Health Insurance: 1,3%; Government Public Health Activities: 4,3 %; Research: 1,6%Structure and Equipment: 10,4%
Pichler et al.	2019	International comparison of health care carbon footprints	OECD (Australia; Austria; Belgium; Canada; Chile; Czech Republic; Germany; Denmark; Spain; Estonia; Finland; France; Great Britain; Greece; Hungary; Ireland; Iceland; Italy; Japan; Korea; Luxembourg; Latvia; Mexico; Netherlands; Norway; Poland; Portugal; Slovakia; Slovenia; Sweden; Turkey; United States; Israel; New Zealand); China; India	~Australia: 19,5 mtCO2e; ~Austria: 6,8 mtCO2e; ~Belgium: 7,5 mtCO2e; ~Canada: 29,7 mtCO2e; ~Chile: 5,9 mtCO2e; ~China: 600,6 mtCO2e; ~Czech Republic: 4,8 mtCO2e; ~Germany: 55,1 mtCO2e; ~Denmark: 4 mtCO2e; ~Spain: 19,2 mtCO2e; ~Estonia: 1,2 mtCO2e; ~Finland: 3,9 mtCO2e; ~France: 34,4 mtCO2e; ~Great Britain: 41,1 mtCO2e; ~Greece: 4,2 mtCO2e; ~Hungary: 2,9 mtCO2e; ~India: 74,1 mtCO2e; ~Ireland: 3,1 mtCO2e; ~Iceland: 0,2 mtCO2e; ~Italy: 23,1 mtCO2e; ~Japan: 114,9 mtCO2e; ~Korea: 33,1 mtCO2e; ~Luxemburg: 0,7 mtCO2e; ~Latvia: 0,5 mtCO2e; ~Mexico: 16,6 mtCO2e; ~Netherlands: 15,8 mtCO2e; ~Norway: 3,6 mtCO2e; ~Poland: 17,4 mtCO2e; ~Portugal: 4 mtCO2e; ~Slovakia: 4,1 mtCO2e; ~Slovenia: 0,7 mtCO2e; ~Sweden: 4,1 mtCO2e; ~Turkey: 17,8 mtCO2e; ~United States: 479,7 mtCO2e; ~Israel(2013): 3,5 mtCO2e; ~New Zealand (2017):1,8 mtCO2e	~Australia: 0.83 tCO2/cap; ~Austria: 0,8 tCO2/cap; ~Belgium: 0,66 tCO2/cap; ~Canada: 0,83 tCO2/cap; ~Chile: 0,73 tCO2/cap; ~China:0,44 tCO2/cap; ~Czech Republic: 0,46 tCO2/cap; ~Germany: 0,68 tCO2/cap; ~Denmark: 0,71 tCO2/cap; ~Spain: 0,41 tCO2/cap; ~Estonia: 0,88 tCO2/cap; ~Finland: 0,72 tCO2/cap; ~France: 0,52 tCO2/cap; ~Great Britain: 0,64 tCO2/cap; ~Greece: 0,39 tCO2/cap; ~Hungary: 0,29 tCO2/cap; ~India: 0,06 tCO2/cap; ~Ireland:0,68 tCO2/cap; ~Iceland: 0,61 tCO2/cap; ~Italy: 0,38 tCO2/cap; ~Japan: 0,9 tCO2/cap; ~Korea: 0,65 tCO2/cap; ~Luxemburg: 1,24 tCO2/cap; ~Latvia: 0,26 tCO2/cap; ~Mexico: 0,13 tCO2/cap; ~Netherlands: 0,93 tCO2/cap; ~Norway: 0,7 tCO2/cap ; ~Poland: 0,46 tCO2/cap; ~Portugal: 0,38 tCO2/cap; ~Slovakia: 0,75 tCO2/cap; ~Slovenia:0,35 tCO2/cap; ~Sweden: 0,42 tCO2/cap; ~Turkey: 0,23 tCO2/cap; ~United States: 1,51 tCO2/cap ; ~Israel(2013):0,43 tCO2/cap; ~New Zealand (2017):0,42 tCO2/cap	~Australia: 4,2%; ~Austria: 6,7%; ~Belgium: 7,7%; ~Canada:5,1%; ~Chile:5,9%; ~China: 6,6%: ~Czech Republic: 4,5%; ~Germany: 6,7%; ~Denmark:6,4%; ~Spain: 5,5%; ~Estonia: 5,2%; ~Finland: 5,3%; ~France: 6,9%; ~Great Britain: 5,9%; ~Greece: 3,8%; ~Hungary: 5,4%; ~India: 3,5%; ~Ireland: 6,7%; ~Iceland: 4,7%; ~Italy: 5,1%; ~Japan: 7,6%; ~Korea: 5,3%; ~Luxemburg: 3,6%; ~Latvia: 3,9%; ~Mexico:3,3%; ~Netherlands: 8,1%; ~Norway: 4,7%; ~Poland: 5,7%; ~Portugal:6%; ~Slovakia:6,7%; ~Slovenia: 4%; ~Sweden: 4,5%; ~Turkey: 3,9%; ~United States: 7,9%; ~Israel(2013): 4,4%; ~New Zealand (2017):4,4%	~Public health care: 62%; Private health care: 31%; Investment: 6% ~Broad Categories: Medical retail: 33%; Hospital 28,6%; ambulatory health care services:18%; Others: 20% ~Detailed Categories: Hospital Care: 2003: 184 (Mt CO2-e); 2004: 188; 2005: 195; 2006: 200; 2007: 206; 2008: 210; 2009: 218; 2010: 222; 2011: 226; 2012: 233; 2013: 238; Physician and Clinical Services: 2003: 57; 2004: 60; 2005: 195; 2006: 65; 2007:68; 2008: 68; 2009: 69; 2010: 70; 2011: 72; 2012: 74; 2013: 77; Other Professional Services: 2003: 7; 2004: 8; 2005: 8; 2006: 8; 2007: 8; 2008: 8; 2009: 9; 2010: 9; 2011: 9; 2012:10; 2013:10; Dental Services: 2003: 11; 2004: 12; 2005: 12; 2006: 12; 2007:12; 2008: 12; 2009: 12; 2010: 12; 2011: 12; 2012:12; 2013: 11; Other Health, Residential, and Personal Care: 2003: 20; 2004: 21; 2005: 22; 2006: 22; 2007: 23; 2008: 23; 2009: 24; 2010: 25; 2011: 25; 2012:25; 2013: 26; Home Health Care: 2003: 9; 2004: 10; 2005: 11; 2006: 12; 2007: 13; 2008: 13; 2009: 14; 2010: 15; 2011: 15; 2012: 16; 2013: 17; Nursing Care Facilities and Continuing Care Retirement Communities: 2003: 35; 2004: 36; 2005: 37; 2006: 37; 2007: 38; 2008: 39; 2009: 39; 2010: 39; 2011: 40; 2012: 40; 2013: 41; Prescription Drugs: 2003: 59; 2004: 63; 2005: 65; 2006: 68; 2007: 71; 2008: 71; 2009: 72; 2010: 69; 2011: 68; 2012: 67; 2013: 68; Durable Medical Equipment: 2003: 12; 2004:13; 2005: 14; 2006: 15; 2007: 16; 2008: 16; 2009: 16; 2010: 16; 2011: 17; 2012: 17; 2013: 18; Other Non-Durable Medical Products: 2003: 11; 2004: 11; 2005: 12; 2006: 12; 2007: 13; 2008: 13; 2009: 13; 2010: 13; 2011: 14; 2012: 15; 2013: 15; Government Administration: 2003: 13; 2004: 13; 2005: 14; 2006: 13; 2007: 13; 2008: 13; 2009: 13; 2010: 13; 2011: 14; 2012: 14; 2013: 15; Net Cost of Health Insurance: 2003: 7; 2004: 7; 2005: 7; 2006: 8; 2007: 8; 2008: 8; 2009: 8; 2010: 8; 2011: 8; 2012: 8; 2013:9; Government Public Health Activities: 2003: 28; 2004: 28; 2005: 28; 2006: 28; 2007: 29; 2008:30; 2009: 31; 2010: 31; 2011: 29; 2012:29; 2013: 29; Research: 2003: 12; 2004: 12; 2005: 13; 2006: 12; 2007: 12; 2008: 12; 2009: 12; 2010: 13; 2011: 12; 2012: 12; 2013: 11; Structures and Equipment: 2003: 45; 2004: 47; 2005: 50; 2006: 51; 2007: 57; 2008: 62; 2009: 59; 2010: 60; 2011: 65; 2012: 70; 2013: 71;
Eckelman et al.	2018	Life cycle environmental emissions and health damages from the Canadian healthcare system: An economic-environmental-epidemiological analysis	Canada	2009:29,6million Mt CO2e; 2010: 31,2; 2011: 31,4; 2012:31,5; 2013:31,4; 2014:32,0; 2015:33,0;	2014: 0.9; n.c.	2014: 4,6%; n.c.	Hospitals (Private): 2009: 0,7 million Mt CO2e; 2010: 0,7; 2011: 0,7; 2012: 0,7; 2013: 0,7; 2014: 0,8; 2015: 0,8; Hospitals (Public): 2009: 6,5; 2010: 6,8; 2011: 7,0; 2012: 7,0; 2013: 7,1; 2014: 7,1; 2015: 7,1; Other Institutions (Private): 2009: 0,7; 2010: 0,7; 2011: 0,7; 2012: 07; 2013: 0,8; 2014: 0,8; 2015: 0,9; Other Institutions (Public): 2009: 1,1; 2010: 1,2; 2011: 1,2; 2012: 1,2; 2013: 1,2; 2014: 1,2; 2015: 1,3; Physicians: 2009: 3,7; 2010: 3,9; 2011: 4,0; 2012: 4,1; 2013: 4,2; 2014: 4,3; 2015: 4,4; Dental Services: 2009: 1,7; 2010: 1,7; 2011: 1,6; 2012: 1,7; 2013: 1,7; 2014: 1,7; 2015: 1,8; Vision Care Services: 2009: 0,6; 2010: 0,5; 2011: 0,5; 2012: 0,5; 2013: 0,5; 2014: 0,5; 2015. 0,6; Other: 2009: 0,4; 2010: 0,4; 2011: 0,4; 2012: 0,5; 2013: 0,5; 2014: 0,5; 2015: 0,6; Prescribed Drugs: 2009: 6,3; 2010: 6,9; 2011: 6,8; 2012: 6,7; 2013: 6,7; 2014: 6,8; 2015: 7,0; Nonprescribed Drugs: 2009: 1,2; 2010: 1,2; 2011:1,2; 2012: 1,2; 2013: 1,2; 2014: 1,2; 2015: 1,3; Capital: 2009: 2,5; 2010: 2,8; 2011: 2,7; 2012: 2,7; 2013: 2,3; 2014: 2,3; 2015: 2,4; Public Health: 2009: 1,6; 2010: 1,6; 2011: 1,7; 2012: 1,7; 2013: 1,7; 2014: 1,8; 2015: 1,9; Administration: 2009: 0,7; 2010: 0,7; 2011: 0,7; 2012: 0,7; 2013: 0,7; 2014: 0,7; 2015: 0,6; Health Research: 2009: 0,4; 2010: 0,4; 2011: 0,4; 2012: 0,4; 2013: 0,4; 2014: 0,4; 2015: 0,4; Other: 2009: 1,6; 2010: 1,7; 2011: 1,7; 2012: 1,7; 2013: 1,7; 2014: 1,8; 2015: 2,0;
Malik et al.	2018	The carbon footprint of Australian health care	Australia	~2013: 33.796 kt CO2e(0,034mt co2e); ~2014: 34.840 kt CO2 (0,035 co2e); ~2015: 35.772 kt CO2e (0,036 co2e) ;	c.n.	7%	~2013: Public Hospital 34,59%; Private Hospitals 9,25%; All other medications 9,25%; Benefit paid Pharmaceuticals 9,81%; Capital expenditures (Buildings) 7,61%; Referred medicals services 5,88%; Community Health and other 5,29%; General Practice 4,21%; Dental services 3,28%; Aids and Appliances 2,88%; Other health practitioner 2,23%; Research 2,1%; Administration 1,3%; Patient Transport Services 1,16%; Public Health 0,83%; ~2014: Public Hospital 34,35%; Private Hospitals 9,79%; All other medications 9,21%; Benefit paid Pharmaceuticals 9,61%; Capital expenditures (Buildings) 7,72%; Referred medicals services 5,99%; Community Health and other 5,25%; General Practice 4,2%; Dental services 3,22%; Aids and Appliances 2,97%; Other health practitioner 2,16%; Research 2,16%; Administration 1,39%; Patient Transport Services 1,16%; Public Health 0,82%; ~2015: Public Hospital 34,36%; Private Hospitals 10,16%; All other medications 9,35%; Benefit paid Pharmaceuticals 9,1%; Capital expenditures (Buildings) 7,76%; Referred medicals services 6,06%; Community Health and other 5,16%; General Practice 4,22%; Dental services 3,31%; Aids and Appliances 2,95%; Other health practitioner 2,16%; Research 1,94%; Administration 1,43%; Patient Transport Services 1,19%; Public Health 0,82%;
Wu	2019	The carbon footprint of the Chinese health-care system: an environmentally extended input-output and structural path analysis study	China	315 Mt CO2e	0,2	2,70%	~Hospitals 51%; Public Hospitals 47%; Private Hospitals 4%; ~NHP pharmaceuticals 18% ~Community health care 10% ~Public Health 4% ~Other health-care institutions 1% ~Construction 15% ~Research 0,3% ~Administration 0,7%
NHSScotland	2008	National Health Service Scotland Carbon Footprint of NHS Scotland(1990-2004)	Scotland	~1998: 2,74 mt CO2e; ~1998: 2,57 mt CO2e; ~2004: 2,63 mt CO2e	c.n.	3,60%	~Scotland: ~1990: ~Travel 23,73%: Patient own travel 10,95%; Visitor Travel 4,75%; Staff Commuting 2,19%; NHS Travel business 6,21%; ~Building Energy Use 34,31%: Grid-supplied electricity 7,3%; On-site fossil fuel gas 6,94%; On-site fossil fuel oil 10,95%; On-site fossil fuel coal 8,76%; Renewables n.d.; ~Procurement 41,98%: Pharmaceuticals 12,41%; Medical Instruments/equipment 5,48%; Health Services 5,11%; Freight Transport 0,37%; Business Services 3,65%; Paper Products 3,29%; Other Manufactured Products 2,56%; Manufactured fuels, chemical, glasses 1,83%; Food and catering 2,92%; Construction 1,46%; Information and Communication technologies 0,73%; Water and Sanitation 0,73%; Waste products and recycling 0,37%; Other Procurement 1,1%; ~1998: ~Travel 27,63%: Patient own travel 12,84 %; Visitor Travel 5,84%; Staff Commuting 2,72%; NHS Travel business 5,84%; ~Building Energy Use 26,07%: Grid-supplied electricity 8,56%; On-site fossil fuel gas 12,06%; On-site fossil fuel oil 4,28%; On-site fossil fuel coal 1,17%; Renewables n.d.; ~Procurement 46,30%: Pharmaceuticals 14,4%; Medical Instruments/equipment 7%; Health Services 4,67%; Freight Transport 0,39%; Business Services 4,67%; Paper Products 3,5%; Other Manufactured Products 2,33%; Manufactured fuels, chemical, glasses 1,56%; Food and catering 2,33%; Construction 1,95%; Information and Communication technologies 0,78%; Water and Sanitation 0,78%; Waste products and recycling 0,39%; Other Procurement 1,56; ~2004: ~Travel 24%: Patient own travel 10%; Visitor Travel 6%; Staff commuting 3%; NHS travel business 6%; ~Building Energy Use 23%; Grid-supplied Electricity 9%; On-site fossil fuels gas 12%; On-site fossil fuels oil 2%; On-site fossil fuels coal 0%; Renewables 0%; ~Procurement 52%; Pharmaceuticals 18%; Medical instruments/equipment 7%;Health Services 6%; Freight Transport 0%; Business Service 5%; Paper Products 4%; Other manufactured Products 3%; Manufactured fuels, chemicals, glasses 2%; Food and catering 2%; Construction 2%; Information and Communication Technology 1%; Water and Sanitation 1%; Waste Products and Recycling 0%; Other Procurement 1%; ~England 2004: ~Travel 18%: Patient own travel 8%; Visitor Travel 2%; Staff Commuting 4%; NHS Travel business 4%; ~Building Energy Use 22%: Grid-supplied electricity 12%; On-site fossil fuel gas 9%; On-site fossil fuel oil 1%; On-site fossil fuel coal 0%; Renewables 0%; ~Procurement 59%: Pharmaceuticals 12%; Medical Instruments/equipment 12%; Health Services n/a; Freight Transport 4%; Business Services 5%; Paper Products 5%; Other Manufactured Products 3%; Manufactured fuels, chemical, glasses 3%; Food and catering 2%; Construction 2%; Information and Communication technologies 2%; Water and Sanitation 1%; Waste products and recycling 1%; Other Procurement 1%
SDU series	2016	Carbon update for the health and care sector in England 2015(1)	NHS England	~1992: 16.58 Mt CO2 ~1993: 15.46 Mt CO2 ~1994: 15.52 Mt CO2 ~1995: 15.48 Mt CO2 ~1996: 15.93 Mt CO2 ~1997: 15.40 Mt CO2 ~1998: 15.77 Mt CO2 ~1999: 16.62 Mt CO2 ~2000: 16.51 Mt CO2 ~2001: 17.97 Mt CO2 ~2002: 17.33 Mt CO2 ~2003: 18.36 Mt CO2 ~2004: 18.62 Mt CO2 ~2007: 21.2 Mt CO2 ~2012: 25 Mt CO2 ~2014: 24.7 Mt CO2 ~2015: 26,6 Mt CO2 ~2017: 27,119 Mt CO2	c.n.	c.n.	~Building Energy Use 18%; ~Travel 13%; ~Commissioned health and care Services from outside system 11%; ~Procurement 57%: Pharmaceuticals (excluding Meter Dose Inhalers) 11%; Business Services 11%; Medical Instruments/Equipment 10%; Food and Catering 5%; Freight Transport 3%; Meter Dose Inhalers 3%; Construction 2%; Manufactured fuels, chemicals and glasses 2%; Paper Products 2%; Waste Products and Recycling 2%; Anaesthetic gases 2%; Other manufactured products 2%, Information and communication Technology 2%; Water and Sanitation 1%
HCH	2019	Health Care´s Climate Footprint	Global; Australia; Austria; Belgium; Brazil; Bulgaria; Canada; China; Croatia; Cyprus; Czech Repub-lic; Denmark; Estonia; Finland; France; Germany; Greece; Hungary; India; Indonesia; Ireland; Italy; Japan; Latvia; Lithuania; Luxembourg; Malta; Mexico; Netherlands; Norway; Poland; Portugal; Romania; Russia; Slovak Republic; Slovenia; Spain; South Korea; Sweden; Switzer-land; Taiwan; Turkey; United Kingdom; United States; Rest-of-World; European Union	Global 2 Gt United States 546.54 Mt; China 342.46Mt; European Union 248.52Mt; Japan 103.55Mt; Russian Federation 76.46Mt; Germany 57.51Mt; Brazil 43.84Mt; United Kingdom 42.5Mt; India 38.8Mt; South Korea 37.26Mt; Canada 35.96Mt; Australia 30.17Mt; France 28.98Mt; Mexico 22.53Mt; Italy 21.31Mt; Spain 16.72Mt; Turkey 14.83Mt; Indonesia 13.59Mt; Netherlands 13.32Mt; Poland 13.02Mt; Taiwan 12.27Mt; Belgium 9.3Mt; Switzerland 8.32Mt; Austria 5.04Mt; Sweden 4.5Mt; Denmark 4.4Mt; Greece 4.15Mt; Czech Republic 3.71Mt; Portugal 3.61Mt; Finland 3.51Mt; Romania 3.08Mt; Norway 3.08Mt; Ireland 2.83Mt; Bulgaria 2.7Mt; Hungary 2.55Mt; Slovak Republic 1.19Mt; Slovenia 0.93Mt; Estonia 0.86Mt; Croatia 0.8Mt; Lithuania 0.5Mt; Latvia 0.5Mt; Luxembourg 0.47Mt; Cyprus 0.34Mt; Malta 0.2Mt	Global 0,28 t CO2e; Australia 1,29 tCO2e; Austria 0,59 tCO2e; Belgium 0,83 tCO2e; Brazil 0,21 tCO2e; Bulgaria 0,37 tCO2e; Canada 1,01 tCO2e; China 0,25 tCO2e; Croatia 0,19 tCO2e; Cyprus 0,3 tCO2e; Czech Republic 0,35 tCO2e; Denmark 0,78 tCO2e; Estonia 0,66 tCO2e; Finland 0,64 tCO2e; France 0,44 tCO2e; Germany 0,71 tCO2e; Greece 0,38 tCO2e; Hungary 0,26 tCO2e; India 0,03 tCO2e; Indonesia 0,05 tCO2e; Ireland 0,61 tCO2e; Italy 0,35 tCO2e; Japan 0,81 tCO2e; Latvia 0,25 tCO2e; Lithuania 0,17 tCO2e; Luxembourg 0,84 tCO2e; Malta 0,45 tCO2e; Mexico 0,18 tCO2e; Netherlands 0,79 tCO2e; Norway 0,64tCO2e; Poland 0,34 tCO2e; Portugal 0,35 tCO2e; Romania 0,15 tCO2e; Russia 0,53 tCO2e; Slovak Republic 0,22 tCO2e; Slovenia 0,45 tCO2e; Spain 0,36 tCO2e; South Korea 0,73 tCO2e; Sweden 0,46 tCO2e; Switzerland 1,02 tCO2e; Taiwan 0,52 tCO2e; Turkey 0,19 tCO2e; United Kingdom 0,66 tCO2e; United States 1,72 tCO2e; Rest-of-World 0,16 tCO2e; European Union 0,49 tCO2e;	United States 7,6; China 3,1; European Union 4,7; Japan 6,4; Russian Federation 4; Germany 5,2; Brazil 4,4; United Kingdom 5,4; India 1,5; South Korea 5,3; Canada 5,2; Australia 5,1; France 4,6; Mexico 3,4; Italy 4; Spain 4,5; Turkey 3,2; Indonesia 1,9; Netherlands 5,9; Poland 3,7; Taiwan 4,6; Belgium 5,5; Switzerland 6,7; Austria 5,2; Sweden 4,4; Denmark 6,3; Greece 3,7; Czech Republic ;3,6 Portugal 4,8; Finland 5; Romania 2,7; Norway 4,3; Ireland 4,4; Bulgaria 6; Hungary 4,3; Slovak Republic 2,8; Slovenia 4,6; Estonia 4,7; Croatia 3,2; Lithuania 2; Latvia 3,2; Luxembourg 3,7; Cyprus 2,9; Malta 4,8; Global 4,4%	~~Scopes ~Global 2,0 gt CO2e: ~Health care facilities and health care owend vehicles 17%; Indirect Emissions 12%; Procurement 71%; ~Australia: Scope1 19%; Scope2 9%; Scope3 72%; ~Austria: Scope1 7%; Scope2 6%; Scope3 87%; ~Belgium: Scope1 11%; Scope2 9%; Scope3 80%; ~Brazil: Scope1 21%; Scope2 6%; Scope3 73%; ~Bulgaria: Scope1 6%; Scope2 43%; Scope3 51%; ~Canada: Scope1 26%; Scope2 13%; Scope3 61%; ~China: Scope1 13%; Scope2 7%; Scope3 80%; ~Croatia: Scope1 17%; Scope2 12%; Scope3 71%; ~Cyprus: Scope1 6%; Scope2 16%; Scope3 78%; ~Czech Republic: Scope1 12%; Scope2 5%; Scope3 83%; ~Denmark: Scope1 12%; Scope2 8%; Scope3 80%; ~Estonia: Scope1 6%; Scope2 51%; Scope3 43%; ~Finland: Scope1 5%; Scope2 13%; Scope3 82%; ~France: Scope1 12%; Scope2 5%; Scope3 83%; ~Germany: Scope1 16%; Scope2 18%; Scope3 66%; ~Greece: Scope1 14%; Scope2 24%; Scope3 62%; ~Hungary: Scope1 16%; Scope2 13%; Scope3 71%; ~India: Scope1 8%; Scope2 11%; Scope3 81%; ~Indonesia: Scope1 16%; Scope2 8%; Scope3 76%; ~Ireland: Scope1 13%; Scope2 9%; Scope3 78%; ~Italy: Scope1 9%; Scope2 8%; Scope3 83%; ~Japan: Scope1 16%; Scope2 17%; Scope3 67%; ~Latvia: Scope1 16%; Scope2 8%; Scope3 76%; ~Lithuania: Scope1 19%; Scope2 9%; Scope3 72%; ~Luxembourg: Scope1 14%; Scope2 4%; Scope3 82%; ~Malta: Scope1 7%; Scope2 11%; Scope3 82%; ~Mexico: Scope1 18%; Scope2 34%; Scope3 48%; ~Netherlands: Scope1 12%; Scope2 5%; Scope3 83%; ~Norway: Scope1 12%; Scope2 4%; Scope3 84%; ~Poland: Scope1 12%; Scope2 31%; Scope3 57%; ~Portugal: Scope1 12%; Scope2 5%; Scope3 83%; ~Romania: Scope1 12%; Scope2 10%; Scope3 78%; ~Russia: Scope1 7%; Scope2 31%; Scope3 62%; ~Slovak Republic: Scope1 20%; Scope2 4%; Scope3 76%; ~Slovenia: Scope1 11%; Scope2 12%; Scope3 77%; ~Spain: Scope1 12%; Scope2 5%; Scope3 83%; ~South Korea: Scope1 12%; Scope2 13%; Scope3 75%; ~Sweden: Scope1 12%; Scope2 5%; Scope3 83%; ~Switzerland: Scope1 10%; Scope2 5%; Scope3 85%; ~Taiwan: Scope1 11%; Scope2 26%; Scope3 63%; ~Turkey: Scope1 2%; Scope2 15%; Scope3 83%; ~United Kingdom: Scope1 12%; Scope2 5%; Scope3 83%; ~United States: Scope1 21%; Scope2 15%; Scope3 64%; ~Rest-of-World: Scope1 %; Scope2 %; Scope3 %; ~European Union: Scope1 14%; Scope2 11%; Scope3 75% ~~Economic Sectors: Generation and distribution of electricity, gas and heat or cooling 40%; Health care facilities operational emissions 13%; Other manufacturing 11%; Agriculture 9%; Other sectors and services 8%; Transport 7%; Pharmaceutical and chemical products 5%; Waste treatment 3%; Other primary Industry 3%
Weisz et al.	2020	Carbon emission trends and sustainability options in Austrian health care	Austria	6.8 Mt CO2eq	0.8t	7%	Hospitals 32%; Investments 9%; Medical retail 20%; Other 20%; Ambulatory 18%
Malik et al.	2021	Environmental impacts of Australia's largest health system	New South Wales, Australia	7908t CO2eq	c.n.	6,6%	-
Eckelman et al.	2020	Health Care Pollution And Public Health Damage In The United States: An Update	USA	2010: 520.5Mt CO2eq; 2011: 514.2 CO2eq; 2012: 486.6 CO2eq; 2013; CO2eq; 2014: 518.6 CO2eq; 2015: 525.6 CO2eq; 2016: 529.8 CO2eq; 2017: 538.1 CO2eq; 2018: 553.5 CO2eq	c.n.	c.n.	~~NHE expenditure categories: ~2010: Hospital care: 35.64%; Physician and Clinical Services: 11.47%; Other Professional Services: 2.21%; Dental Services: 3.05%; Other Health, Residential, and Personal Care: 6.72%; Home Health Care: 1.73%; Nursing Home Facilities and Continuing Care Retirement Communities: 6.99%; Prescription Drugs: 11.41%; Durable Medical Equipment: 1.77%; Other Non-Durable Medical Products: 2.46%; Federal Administration Expenditures: 1.44%; State and Local Administration Expenditures: 0.56%; Net Cost of Health Insurance: 1.31%; Public Health Activity: 5.05%; Research: 2.07%; Structures and Equipment: 6.11% ~2011: Hospital care: 35.57%; Physician and Clinical Services: 11.65%; Other Professional Services: 2.26%; Dental Services: 3.01%; Other Health, Residential, and Personal Care: 6.55%; Home Health Care: 1.79%; Nursing Home Facilities and Continuing Care Retirement Communities: 6.94%; Prescription Drugs: 11.09%; Durable Medical Equipment: 1.85%; Other Non-Durable Medical Products: 2.57%; Federal Administration Expenditures: 1.54%; State and Local Administration Expenditures:0.60%; Net Cost of Health Insurance: 1.24%; Public Health Activity: 4.80%; Research: 2.00%; Structures and Equipment: 6.59% ~2012: Hospital care: 35.64%; Physician and Clinical Services: 11.73%; Other Professional Services: 2.26%; Dental Services: 2.92%; Other Health, Residential, and Personal Care: 6.62%; Home Health Care: 1.81%; Nursing Home Facilities and Continuing Care Retirement Communities: 6.76%; Prescription Drugs: 10.81%; Durable Medical Equipment: 1.85%; Other Non-Durable Medical Products: 2.57%; Federal Administration Expenditures: 1.54%; State and Local Administration Expenditures:0.58%; Net Cost of Health Insurance: 1.27%; Public Health Activity: 4.81%; Research: 1.85%; Structures and Equipment: 6.99% ~2013: Hospital care: 35.73%; Physician and Clinical Services: 11.76%; Other Professional Services: 2.24%; Dental Services: 2.81%; Other Health, Residential, and Personal Care: 6.67%; Home Health Care 1.84%; Nursing Home Facilities and Continuing Care Retirement Communities: 6.71%; Prescription Drugs: 10.46%; Durable Medical Equipment: 1.86%; Other Non-Durable Medical Products: 2.59%; Federal Administration Expenditures: 1.6%; State and Local Administration Expenditures: 0.64%; Net Cost of Health Insurance: 1.34%; Public Health Activity: 4.73%; Research: 1.72%; Structures and Equipment: 7.25% ~2014: Hospital care: 35.27%; Physician and Clinical Services: 11.9%; Other Professional Services: 2.28%; Dental Services: 2.7%; Other Health, Residential, and Personal Care: 6.52%; Home Health Care 1.87%; Nursing Home Facilities and Continuing Care Retirement Communities: 6.46%; Prescription Drugs: 11.61%; Durable Medical Equipment: 2.06%; Other Non-Durable Medical Products: 2.7%; Federal Administration Expenditures: 1.72%; State and Local Administration Expenditures: 0.69%; Net Cost of Health Insurance: 1.33%; Public Health Activity: 4.69%; Research: 1.58%; Structures and Equipment: 6.61% ~2015: Hospital care: 34.84%; Physician and Clinical Services: 12.04%; Other Professional Services: 2.25%; Dental Services: 2.59%; Other Health, Residential, and Personal Care: 6.6%; Home Health Care1.86%; Nursing Home Facilities and Continuing Care Retirement Communities: 6.18%; Prescription Drugs: 12.27%; Durable Medical Equipment: 2.05%; Other Non-Durable Medical Products: 2.74%; Federal Administration Expenditures: 1.73%; State and Local Administration Expenditures: 0.65%; Net Cost of Health Insurance: 1.29%; Public Health Activity: 4.74%; Research: 1.48%; Structures and Equipment: 6.66% ~2016: Hospital care: 35.05%; Physician and Clinical Services: 12.31%; Other Professional Services:2.27%; Dental Services: 2.57%; Other Health, Residential, and Personal Care: 6.61%; Home Health Care 1.85%; Nursing Home Facilities and Continuing Care Retirement Communities: 6.02%; Prescription Drugs: 12.12%; Durable Medical Equipment: 2.06%; Other Non-Durable Medical Products: 2.79%; Federal Administration Expenditures: 1.72%; State and Local Administration Expenditures: 0.66%; Net Cost of Health Insurance: 1.26%; Public Health Activity: 4.66%; Research: 1.45%; Structures and Equipment: 6.61% ~2017: Hospital care: 35.01%; Physician and Clinical Services: 12.47%; Other Professional Services: 2.27%; Dental Services: 2.55%; Other Health, Residential, and Personal Care: 6.69%; Home Health Care 1.88%; Nursing Home Facilities and Continuing Care Retirement Communities: 5.82%; Prescription Drugs: 11.89%; Durable Medical
Tennison et al.	2021	Health care's response to climate change: a carbon footprint assessment of the NHS in England	England	~1990: 33.8 Mt CO2eq ~1991: 33 Mt CO2eq ~1992: 33.2 Mt CO2eq ~1993: 30.8 Mt CO2eq ~1994:30.3 Mt CO2eq ~1995:30.4 Mt CO2eq ~1996: 29.4 Mt CO2eq ~1997 29.3 Mt CO2eq ~1998: 27.8 Mt CO2eq ~1999: 28.2 Mt CO2eq ~2000:27.5 Mt CO2eq ~2001: 26.8 Mt CO2eq ~2002: 26.1 Mt CO2eq ~2003: 27 Mt CO2eq ~2004: 27.1 Mt CO2eq ~2005: 27.6 Mt CO2eq ~2006: 27 Mt CO2eq ~2007: 28.3 Mt CO2eq ~2008: 28.7 Mt CO2eq ~2009: 28.4 Mt CO2eq ~2010: 28.1 Mt CO2eq ~2011: 27.3 Mt CO2eq ~2012: 27.9 Mt CO2eq ~2013: 28.3 Mt CO2eq ~2014: 28.3 Mt CO2eq ~2015: 27.3 Mt CO2eq ~2016: 26.4 Mt CO2eq ~2017: 25.7 Mt CO2eq ~2018: 25.4 Mt CO2eq ~2019 25 Mt CO2eq	~1990: 0.709 ~1991: 0.689 ~1992: 0.696 ~1993: 0.640 ~1994: 0.629 ~1995: 0.628 ~1996: 0.603 ~1997: 0.603 ~1998: 0.57 ~1999: 0.574 ~2000: 0.558 ~2001: 0.542 ~2002: 0.526 ~2003: 0.54 ~2004: 0.54 ~2005: 0.546 ~2006: 0.529 ~2007: 0.552 ~2008: 0.554 ~2009: 0.544 ~2010: 0.535 ~2011: 0.514 ~2012: 0.522 ~2013: 0.525 ~2014: 0.515 ~2015: 0.498 ~2016: 0.478 ~2017: 0.463 ~2018: 0.454 ~2019: 0.445	c.n.	~1990: Delivery of care: 47.93%; Supply Chain: 46.15%; Commissioned Healthcare: 0.56%; Travel: 5.62% ~1991: Delivery of care: 47.27%; Supply Chain: 46.06%; Commissioned Healthcare: 0.61%; Travel: 6.06% ~1992: Delivery of care: 45.81%; Supply Chain: 47.60%; Commissioned Healthcare: 0.60%; Travel: 5.99% ~1993: Delivery of care: 45.78%; Supply Chain: 46.75%; Commissioned Healthcare: 0.65%; Travel: 6.49% ~1994: Delivery of care: 46.20%; Supply Chain: 46.53%; Commissioned Healthcare: 0.66%; Travel: 6.93% ~1995: Delivery of care: 43.09%; Supply Chain: 49.01%; Commissioned Healthcare: 0.99%; Travel: 6.91% ~1996: Delivery of care: 44.03%; Supply Chain: 47.44%; Commissioned Healthcare: 1.02%; Travel: 7.17% ~1997: Delivery of care: 41.63%; Supply Chain: 50.51%; Commissioned Healthcare: 1.02%; Travel: 7.51% ~1998: Delivery of care: 44.96%; Supply Chain: 46.40%; Commissioned Healthcare: 1.08%; Travel: 7.91% ~1999: Delivery of care: 43.62%; Supply Chain: 47.16%; Commissioned Healthcare: 1.06%; Travel: 7.80% ~2000: Delivery of care: 41.45%; Supply Chain: 49.09%; Commissioned Healthcare: 1.09%; Travel: 8.36% ~2001: Delivery of care: 41.04%; Supply Chain: 49.25%; Commissioned Healthcare: 1.12%; Travel: 8.58% ~2002: Delivery of care: 40.61%; Supply Chain: 49.81%; Commissioned Healthcare: 1.15%; Travel: 8.43% ~2003: Delivery of care: 40.00%; Supply Chain: 49.63%; Commissioned Healthcare: 1.48%; Travel: 8.89% ~2004: Delivery of care: 37.27%; Supply Chain: 52.77%; Commissioned Healthcare: 1.48%; Travel: 8.49% ~2005: Delivery of care: 38.77%; Supply Chain: 50.72%; Commissioned Healthcare: 1.45%; Travel: 9.06% ~2006: Delivery of care: 38.15%; Supply Chain: 50.74%; Commissioned Healthcare: 1.48%; Travel: 9.63% ~2007: Delivery of care: 34.63%; Supply Chain: 54.42%; Commissioned Healthcare: 1.77%; Travel: 9.54% ~2008: Delivery of care: 33.10%; Supply Chain: 56.10%; Commissioned Healthcare: 1.74%; Travel: 9.06% ~2009: Delivery of care: 33.10%; Supply Chain: 56.69%; Commissioned Healthcare: 2.11%; Travel: 8.10% ~2010: Delivery of care: 30.96%; Supply Chain: 58.01%; Commissioned Healthcare: 2.49%; Travel: 8.90% ~2011: Delivery of care: 30.40%; Supply Chain: 57.14%; Commissioned Healthcare: 4.03%; Travel: 8.42% ~2012: Delivery of care: 31.54%; Supply Chain: 56.27%; Commissioned Healthcare: 3.94%; Travel: 8.24% ~2013: Delivery of care: 28.98%; Supply Chain: 57.95%; Commissioned Healthcare: 4.59%; Travel: 8.48% ~2014: Delivery of care: 27.86%; Supply Chain: 58.93%; Commissioned Healthcare: 4.29%; Travel: 8.57% ~2015: Delivery of care: 27.11%; Supply Chain: 60.44%; Commissioned Healthcare: 4.03%; Travel: 8.79% ~2016: Delivery of care: 26.52%; Supply Chain: 60.61%; Commissioned Healthcare: 3.79%; Travel: 9.09% ~2017: Delivery of care: 26.07%; Supply Chain: 61.09%; Commissioned Healthcare: 3.89%; Travel: 9.34% ~2018: Delivery of care: 25.20%; Supply Chain: 61.42%; Commissioned Healthcare: 3.94%; Travel: 9.45% ~2019: Delivery of care: 24.40%; Supply Chain: 62.40%; Commissioned Healthcare: 4.00%; Travel: 9.60%
Lenzen et al.	2020	The environmental footprint of health care: a global assessment	Global (189 countries)	~2000: Global: 1.70Gt CO2eq ~2001: Global: 1.70Gt CO2eq ~2002: Global: 1.76Gt CO2eq ~2003: Global: 1.87Gt CO2eq ~2004: Global: 1.87Gt CO2eq ~2005: Global: 1.92Gt CO2eq ~2006: Global: 1.98Gt CO2eq ~2007: Global: 2.04Gt CO2eq ~2008: Global: 2.04Gt CO2eq ~2009: Global: 1.98Gt CO2eq ~2010: Global: 2.10Gt CO2eq ~2011: Global: 2.14Gt CO2eq ~2012: Global: 2.19Gt CO2eq ~2013: Global:2.24Gt CO2eq ~2014: Global:2.29Gt CO2eq ~2015: Global:2.40Gt CO2eq; USA: 595.14Mt Co2eq; Japan: 190.52Mt Co2eq; Germany: 64.01Mt Co2eq; China: 375.50Mt Co2eq; France: 24.84Mt Co2eq; UK: 42.31Mt Co2eq; Russia: 219.64Mt Co2eq; Brazil: 103.28Mt Co2eq; Italy: 18.57Mt Co2eq; Canada: 43.09Mt Co2eq; Australia: 21.77Mt Co2eq; Spain: 31.32Mt Co2eq; Netherlands: 13.38Mt Co2eq; Norway: 4.23Mt Co2eq; Belgium: 7.22Mt Co2eq; Mexico: 16.55Mt Co2eq; Argentina: 16.38Mt Co2eq; Austria: 6.60Mt Co2eq; Israel: 6.65Mt Co2eq; Finland: 5.10Mt Co2eq; Poland: 13.20Mt Co2eq; South Korea: 24.88Mt Co2eq; Turkey: 11.95Mt Co2eq; Colombia: 5.08Mt Co2eq; Ireland: 3.91Mt Co2eq; Singapore: 8.60Mt Co2eq; Portugal 4.84Mt Co2eq; Thailand 13.36Mt Co2eq; Iran: 39.31Mt Co2eq; Indonesia: 14.29Mt Co2eq; Denmark: 3.37Mt Co2eq; South Africa: 15.93Mt Co2eq; Chile: 5.46Mt Co2eq; Greece: 4.00Mt Co2eq; New Zealand: 3.45Mt Co2eq; Czech Republic: 5.68Mt Co2eq; Taiwan: 10.49Mt Co2eq;	Norway: 0.81; Sweden: 0.58; Switzerland: 0.76; USA: 1.86; Finland: 0.93; Australia: 0.91; Netherlands: 0.79; Germany: 0.78; Belgium: 0.64; Japan: 1.49; Ireland: 0.83; Canada: 1.18; France: 0.37; Austria: 0.76; Israel: 0.82; Singapore: 1.55; Greenland: 76.99; UK 0.65; Denmark: 0.59; Italy: 0.31; New Zealand: 0.75; Spain: 0.67; Portugal: 0.46; Slovenia: 0.43; Curacao: 15.44; Russia: 1.53; Malta: 0.55; Uruguay: 0.79; Greece: 0.36; Czech Republic: 0.54; Slovakia: 1.27; Estonia 0.65; Hungary: 0.3; Chile: 0.31; Brazil: 0.5; Argentina: 0.38; Latvia: 0.36; Lithuania: 0.45; Poland: 0.35; South Korea: 0.49; Romania: 0.29; Colombia: 0.11; Mexico: 0.13; Taiwan: 0.45; Mauritius: 0.36; The former Yugoslav Republic of Macedonia: 0.36; Kazakhstan: 0.41; Turkey: 0.15; South Africa: 0.29; Thailand: 0.19; Malaysia: 0.25; China: 0.27; Georgia: 0.21; Iran: 0.50; Peru: 0.14; Ecuador: 0.09; Kuwait: 0.39; Ukraine: 0.27; Paraguay: 0.14; Venezuela: 0.15; Phillippines: 0.05; Kenya: 0.04; Uzbekuistan: 0.11; Indonesia: 0.06; India: 0.22; Viet Nam: 0.16	USA: 6.69%; Japan: 7.07%; Germany: 4.51%; China 3.1%; France: 3.19%; UK: 5%; Russia: 10.66%; Brazil: 3.11%; Italy: 2.31%; Canada: 4.76%; Australia: 3.25%; Spain: 5.39%; Netherlands: 4.02%; Sweden: 4.46%; India: 7.79%; Switzerland: 4.82%; Norway: 4.39%; Belgium: 3.45%; Mexico: 2.03%; Argentina: 3.88%; Austria: 4.54%; Israel: 4.99%; Finland: 4.26%; Poland: 3.01%; South Korea: 2.8%; Turkey: 1.71%; Colombia: 2.35%; Ireland: 3.98%; Singapore: 3.40%; Portugal: 4.83%; Thailand: 2.21%; Iran: 3.96%; Indonesia: 1.68%; Denmark: 3.78%; South Africa: 2.5%; Chile: 3.43%; Greece: 2.48%; New Zealand: 3.56%; Czech Republic: 3.08%; Taiwan: 1.81%; Phillippines: 2.74%; Romania: 3.52%; Malaysia: 2.04%; Hungary: 2.91%; Peru: 4.39%; Ukraine: 3.3%; Slovakia: 2.75%, Kazakhstan: 2.24%; Uruguay: 5.97%; Kenya: 2.71%; Viet Nam: 2.44%; Slovenia: 3.26%; Ecuador: 2.17%; Venezuela: 0.87%; Uzbekistan: 2.22%; Lithuania: 2.09%; Latvia: 3.72%; Estonia: 3.26%: Georgia: 4.13%; Paraguay: 1.68%; The former Yugoslav Republic off Macedonia: 4.12%; Kuwait: 1.45%; Malta: 3.41%; Mauritius: 3.36%; Caracao: 6.99%; Kyrgyzstan: 3.13%	-

Steenmeijer et al.	2022	The environmental impact of the Dutch health-care sector beyond climate change: an input–output analysis	Netherlands	17575 kt CO_2eq	c.n.	7,30%	Scope 1 (Operational impacts (including anaesthetic gases)): 9,0%; Scope 2 (total): 11,1%, Scope 2 (Electricity): 10,5%, Scope 2 (Steam and hot water supply) 0,6%; Scope 3 (total): 79,9%, Scope 3(Coal & petroleum): 1,1%, Scope 3(Construction): 1,5%, Scope 3(Electrical, electronic &measuring equipment): 7,6%, Scope 3(Food, tobacco & agricultural products): 5,8%, Scope 3(Furniture & timber): 0,1%, Scope 3(General and special machinery): 1%, Scope 3(Metal products): 0,3%, Scope 3(Minerals & metals): 0,6%, Scope 3(Natural gas & gaseous fuels): 0,6%, Scope 3(Non-metallic mineral products): 0,3%, Scope 3(Paper products): 1,1%, Scope 3(Pharmaceuticals & chemical products): 41,2%), Scope 3(pMDI propellant releases): 0,4%, Scope 3(Private travel by patients & visitors (3,3%), Scope 3(Services): 6,7%, Scope 3(Textile): 0,4%, Scope 3(Transport):3,7%, Scope 3(Transport equipment): 0,1%, Scope 3(Waste management % disposal): 1,6%, Scope 3(Water distribution): 0,2%, Scope 3(Private travel by patients and visitors): 2%

Appendix: Method and transparency

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Method	Demand Data source (detail)	Demand Data year	Number of demand/Expenditure categories	I-O table data source	I-O table data year	I-O model	Number of production sectors	Source of emission data/satelite account	Included Greenhouse Gases	Concardance matrix reported	Sensitivity/Uncertainty Analysis	Discussion of limitations
Top-Down	"National Medical Expenses Statistics"	2011	16	Ministry of internal Affairs and Communication	2011	SRIO (JIOT)	397	Japan National Report of GHGs Inventory (NRI)	CO2, CH4, N2O, HFCs, PFCs, SF6 and NF3	No	No	Yes
Top-Down	US National Health Expenditure Accounts	2003–2013	15	Federal Bureau of Economic Analysis	2002	SRIO	400+	EIOLCA	Equivalents	Yes	No	Yes
Top-Down	OECD: OECD health statistics database; China+India: World Bank health care expenditure	2014	OECD: 19	Eora	2014	MRIO (Eora)	14839	EDGAR	CO2	Available upon request	No	Yes
Top-Down	National Health Expenditures (NHEX) database maintained by the Canadian Institute for Health Information (CIHI)	2009-2015	13	(Statistics Canada)	2009	SRIO (Open IO-Canada)	112 sectors, 238 commodities	Statistics Canada Environmental Accounts and the Canadian National Pollutant Release Inventory	carbon dioxide, methane, and nitrous	Yes	No	Yes
Top-Down	Australian Institute of Health and Welfare (AIHW)	2015	16	Australian Bureau of Statistics	2014-2015	SRIO (Individually constructed)	360	Sydney University IELab	Equivalents	No	Monte-Carlo	Yes
Top-Down	national input–output table, China Health and Family Planning Statistics, China Construction Statistics, and China Science and Technology Statistics yearbooks	2013	8	National Bureau of Statistics of China	2012	SRIO	46	Climate Change Department of National Development and Reform Commission of the People's Republic of China. The People's Republic of China First Biennial Update Report on Climate Change	CO2, CH4, and N2O emissions	No	Monte-Carlo + Robustness (w/ onsite-emission in the medical institution sector) + Sensitivity (w/ energy intensities of floorspace of commercial buildings)	Yes
Hybrid	Scottish Government health expenditure	1990-2004	17	Scottish Government	1990-2004	SRIO (Scottish Government Input-Output tables)	123	UK National Statistics Environmental Accounts	CO2	Allocation without quantitative description	No	No
Hybrid	English Government	2004-2015	5	DEFRA	2004-2015	MRIO (UK-MRIO)	178	National Statistics Environmental Accounts	CO2 Beginning in 2010: CH4, N2O, HFCs, PFCs, SF6	Allocation without quantitative description	No	No
Top-Down	OECD health statistics database; World Health Organization, "Global Health Expenditure Database,"	2014	No	WIOD	2014	MRIO (WIOD)	2408	CO2: WIOD; Methane and Nitrous oxide: PRIMAP	carbon dioxide, methane and nitrous oxide gases	Reference to Pichler et al. (2019)	No	Yes
Top-Down	OECD Health Statistics 2017 supplied by the Austrian national statistical office	2014	9	Eora	2014	MRIO (Eora)	15909	EORA taken from EDGAR	CO2	Reference to Pichler et al. (2019)	No	Yes
Top-Down	Australian Institute of Health and Welfare	2016-2017	16	Australian Bureau of Statistics (ABS)	2017	SRIO (Individually constructed)	2880	No	No	No	No	Yes
Top-Down	National Health Expenditure Accounts of the Centers for Medicare and Medicaid Services (CMS)	2010-2018	16	Bureau of Economic Analysis	2012	SRIO (US Environmentally-Extended Input-Output model)	405	Inventory of U.S. Greenhouse Gas Emissions and Sinks	No	Yes	No	Yes
Hybrid	Public Expenditure Statistical Analysis Supply and Use tables from HM Treasury	1990-2019	19	DEFRA	1997-2016	MRIO (UK-MRIO)	424	UK MRIO	carbon dioxide [CO2], methane [CH4], nitrous oxide [N2O], and some categories of fluorinated gases/all Kyoto Protocol greenhouse gases	Yes	No	Yes
Top-Down	EORA	2000-2015	163	Eora	2000-2015	MRIO (Eora)	14838	EORA taken from EDGAR	carbon dioxide [CO2], methane, nitrous oxide, hydrofluorocarbon, chlorofluorocarb	No	Uncertainty	Yes
Hybrid	Centraal Bureau voo	2016	3	EXIOBASE	2016	MRIO (EXIOBASE)	7.987	EXIOBASE	CO2, CH4, N2O	Yes	No	Yes

Appendix: Transparency Score

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Author	**Year**	**Author (Year)**	**Title**	Health Care System	Total Carbon Footprint	tCO2/capi-ta	% of total emission	Breakdown	Method	Demand Data source	Demand Data year	Number of demand/ Expend-iture cate-gories	I-O table data source	I-O table data year	Multiregionality of the model	Number of production sectors	Source of emission data/ satelite account	Included Green-house Gases	Concordance matrix reported	Sensitivity /Un-certainty Analysis	Dis-cussion of limitations		
Nansai et al.	2020	Nansai et al. (2020)	Carbon footprint of Japanese health care services from 2011 to 2015	Japan	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	14	82,35%
Eckelman et al.	2016	Eckelman et al. (2016)	Environmental Impacts of the U.S. Health Care System and Effects on Public Health	USA	1	0	1	1	1	1	1	1	1	1	1	1	1	0,5	1	0	1	14,5	85,29%
Pichler et al.	2019	Pichler et al. (2019)	International comparison of health care carbon footprints	OECD countries; China; India	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	16	94,12%
Eckelman et al.	2018	Eckelman et al. (2018)	Life cycle environmental emissions and health damages from the Canadian healthcare system: An economic-environmental-epidemiological analysis	Canada	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	16	94,12%
Malik et al.	2018	Malik et al. (2018)	The carbon footprint of Australian health care	Australia	1	0	1	1	1	1	1	1	1	1	1	1	1	0,5	0	1	1	14,5	85,29%
Wu	2019	Wu (2019)	The carbon footprint of the Chinese health-care system: an environmentally extended input-output and structural path analysis study	China	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	16	94,12%
NHSScotland	2008	NHSScotland (2008)	National Health Service Scotland Carbon Footprint of NHS Scotland(1990-2004)	Scotland	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	13	76,47%
SDU series	2016	SDU series (2016)	Carbon update for the health and care sector in England 2015	NHS England	1	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	12	70,59%
HCH	2019	HCH (2019)	Health Care´s Climate Footprint	43 countries	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	15	88,24%

Weisz et al.	2020	Weisz et al. (2020)	Carbon emission trends and sustainability options in Austrian health care	Austria	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	16	94,12%
Malik et al.	2021	Malik et al. (2021)	Environmental impacts of Australia's largest health system	New South Wales, Australia	1	0	1	0	1	1	1	1	1	1	1	1	0	0	1	0	1	12	70,59%
Eckelman et al.	2020	Eckelman et al. (2020)	Health Care Pollution And Public Health Damage In The United States: An Update	USA	1	0	0	1	1	1	1	1	1	1	1	1	1	0	1	0	1	13	76,47%
Tennison et al.	2021	Tennison et al. (2021)	Health care's response to climate change: a carbon footprint assessment of the NHS in England	England	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	15	88,24%
Lenzen et al.	2020	Lenzen et al. (2020)	The environmental footprint of health care: a global assessment	189 countries	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	15	88,24%
Steenmeije	2022	Steenmeijer et al. (2022)		Netherland	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	15	88,24%
					15	7	12	13	15	15	15	14	15	15	15	15	1[illegible]	12	11	3	13		
					100,00%	46,67%	80,00%	86,67%	100,00%	100,00%	100,00%	93,33%	100,00%	100,00%	100,00%	100,00%	7[illegible]33%	80,00%	73,33%	20,00%	86,67%		