HEALTH CARE'S CLIMATE FOOTPRINT

HOW THE HEALTH SECTOR CONTRIBUTES TO THE GLOBAL CLIMATE CRISIS AND OPPORTUNITIES FOR ACTION

Appendix B

Detailed Methodology

Health Care Without Harm

ARUP

Health Care Without Harm
Climate-smart health care series
Green Paper Number One

Produced in collaboration with Arup
September 2019

About this document: This is Appendix B to the first in a series of papers that Health Care Without Harm and its partners, including Arup, aim to produce over the coming three years. The series will define health care's climate footprint and outline a set of actions the sector can take to align itself with the ambition of the Paris Agreement while simultaneously achieving global health goals. Future Green Paper topics will include a global road map for health care decarbonization and resilience; strategies for national and sub-national governments to develop and implement climate-smart health care policies; decarbonizing the health care supply chain; recommendations for green, climate resilient, decarbonized health development assistance; and more.

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Technical Advisory Group: Health Care Without Harm established a Climate Measurement Technical Advisory Group to guide the development of the methodology and other research for this and forthcoming studies, so as to ensure: accuracy and integrity; integration of aspects unique to health care into climate footprint measurement; alignment with best practices in the field of climate footprint measurement; flexibility for regional differences in health systems; and uptake by key stakeholders.

The advisory group, which met virtually at key moments in the project's development, is drawn from international organizations, health and health care institutions, climate organizations and academic experts. Members include:

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B1 Introduction: Greenhouse Gas emissions estimation

The mathematics of calculating a climate footprint for an organization are relatively straightforward. For each process or product that has an impact, the climate footprint is calculated by multiplying the units of output of process (i.e. quantity of activity) by the amount of carbon associated with the process per unit of output (carbon intensity).

Given that almost all activities in the economy have carbon impacts, the complications in the process of calculating footprints come from sourcing data (i.e. data for both quantity of activity, and appropriate carbon intensity), tracking and aggregating impacts through complex value chains, and using appropriate accounting methods to accurately attribute impacts within systems and their boundaries.

Environmentally Extended Multi-Region Input-Output (EE-MRIO) models are a particularly useful tool for undertaking such analyses. An EE-MRIO is based on an 'input-output' method that tracks all financial transactions between industrial sectors and consumers within an economy. By adding environmental information, such as greenhouse gas emissions, to each sector it becomes possible to assign an environmental burden (a "footprint") to these financial transactions. Similar to following the flow of money or costs, from production to consumption, an environmentally extended input-output model allows following the flow of environmental footprints along supply and production chains. As each production step adds an environmental burden, the result is a life-cycle inventory of impacts of production and consumption, e.g. GHG emissions of companies, organizations, sectors, cities/regions or countries.

EE-MRIO is the modelling approach applied in this study and is an efficient tool for covering the global health sector scope and the direct and indirect emission sources associated with this system. A key strength of the EE-MRIO model is its full global economy coverage and the avoidance of system truncation errors in determining climate footprint (i.e. carbon emission omissions that might result due to gaps in a model). However, one of the constraints of using an EE-MRIO is the fixed reporting structures they apply due to models being based on national supply and demand accounts and the need to aggregate these to a common form of account that matches across national economies.

For brevity the acronym MRIO is typically used to refer to these tables, including those with environmental extensions.

B2 Definition of health care sector

This study uses the World Health Organization (WHO) definition of the health sector [1], which states:

"all organizations, institutions, and resources that are devoted to producing health actions. A health action is defined as any effort, whether personal health care, public health service or inter-sectoral initiative, whose primary purpose is to improve health"

The OECD health statistics database uses the System of Health Accounts (SHA) 2011 [1], co-published by the OECD, Eurostat and WHO. Using the WHO definition above as a foundation, the SHA defines which activities in the economy constitute health care and reports expenditures in those activities in three categorizations: financing schemes, functions and providers. Given the primary audience of this paper is those responsible for taking climate action within health care providers, this categorization is chosen for this study. The categorization with its subsections is given in Table B1.

Table B1: Providers categorization from the System of Health Accounts.

Code	Description
HP.1	Hospitals
HP.1.1	General hospitals
HP.1.2	Mental health hospitals
HP.1.3	Specialised hospitals (other than mental health hospitals)
HP.2	Residential long-term care facilities
HP.2.1	Long-term nursing care facilities
HP.2.2	Mental health and substance abuse facilities
HP.2.9	Other residential long-term care facilities
HP.3	Providers of ambulatory health care
HP.3.1	Medical practices
HP.3.1.1	Offices of general medical practitioners
HP.3.1.2	Offices of mental medical specialists
HP.3.1.3	Offices of medical specialists (other than mental medical specialists)
HP.3.2	Dental practice
HP.3.3	Other health care practitioners
HP.3.4	Ambulatory health care centres
HP.3.4.1	Family planning centres

Code	Description
HP.3.4.2	Ambulatory mental health and substance abuse centres
HP.3.4.3	Free-standing ambulatory surgery centres
HP.3.4.4	Dialysis care centres
HP.3.4.9	All other ambulatory centres
HP.3.5	Providers of home health care services
HP.4	Providers of ancillary services
HP.4.1	Providers of patient transportation and emergency rescue
HP.4.2	Medical and diagnostic laboratories
HP.4.9	Other providers of ancillary services
HP.5	Retailers and other providers of medical goods
HP.5.1	Pharmacies
HP.5.2	Retail sellers and other suppliers of durable medical goods and medical appliances
HP.5.9	All other miscellaneous sellers and other suppliers of pharmaceuticals and medical goods
HP.6	Providers of preventive care
HP.7	Providers of health care system administration and financing
HP.7.1	Government health administration agencies
HP.7.2	Social health insurance agencies
HP.7.3	Private health insurance administration agencies
HP.7.9	Other administration agencies
HP.8	Rest of economy
HP.8.1	Households as providers of home health care
HP.8.2	All other industries as secondary providers of health care
HP.8.9	Other industries
HP.9	Rest of the world

The definition of health care described above is comprehensive, and includes activities perhaps not immediately considered part of health care provision. For example, HP.5 includes pharmacies and retailers selling health products directly to consumers, while HP.6 includes organizations engaged in preventative health campaigns such as those promoting active lifestyles. In this sense the definition goes beyond what might be considered 'health care.' In this study the term 'health care sector' is taken to mean the full range of activities described above.

B3 Database choice

This study is conducted using the World Input-Output Database (WIOD), a global MRIO model funded by the European Commission [2]. WIOD provides a full model of global trade, using a consistent 56 sector definition to describe the economies of 43 nations in detail, described in Table B2, with an aggregated rest-of-world category ensuring full global coverage. It is a highly regarded model, which has been widely used and validated in the literature.

Table B2: WIOD nations by geographical location and income level.

Income level:	High	Upper middle	Lower middle	Low
North America	USA, Canada	-	-	-
Latin America and the Caribbean	-	Brazil, Mexico	-	-
Middle East and North Africa	-	-	-	-
Europe and Central Asia	EU28 minus Bulgaria, Romania (next column), Switzerland, Norway	Bulgaria, Romania, Russian Federation, Turkey	-	-
East Asia and Pacific	Australia, Japan, South Korea, Taiwan	China	Indonesia	-
South Asia	-	-	India	-
Sub-Saharan Africa	-	-	-	-

B4 Greenhouse Gas emissions

The WIOD dataset provides a detailed environmental extension covering carbon dioxide emissions for all nations and sectors [3]. Other GHGs are not included, so where appropriate a customized approach to including these emissions is used to meet the goals of this work.

The Greenhouse Gas Protocol (GHGP) lists 6 classes of greenhouse gas to be included in foot-printing calculations [4]:

- carbon dioxide;
- methane;
- nitrous oxide;
- hydrofluorocarbons (HFCs);
- perfluorocarbons (PFCs);
- sulphur hexafluoride (SF_6).

After carbon dioxide, the main contributors to global warming are methane and nitrous oxide, with these three gases accounting for 98% of global GHG emissions. These gases are added to our methodology through allocating emissions reported in the PRIMAP emissions database [5] to WIOD categories.

The PRIMAP database reports methane and nitrous oxide emissions against five aggregated categories: Energy, Industrial Processes and Product Use, Agriculture, Waste, and Other. Of these five categories, three directly correspond to a single WIOD category and thus emissions could be attributed to these categories directly, as shown in

Table B3. For the Industrial Processes and Product Use category, PRIMAP reports values for two subcategories which align directly with WIOD categories, chemical industry and metal industry, which are included in the model. For the other subcategories of Industrial Processes and Product Use and emissions in the Other category, accurate disaggregation to match WIOD categories was not possible with the available information; we estimate the emissions in these subcategories amount to 0.001% of the global total.

This approach allows us to incorporate virtually all global methane emissions and 93.6% of global nitrous oxide emissions into our model. Carbon dioxide, methane, and nitrous oxide accounted for 98.4% of global GHG emissions in 2014 [5]. The remaining emissions come from fluorinated gases (HFCs, PFCs and SF_6) for which PRIMAP data is not available in a suitable form to include in this work. Emissions all arise from the Industrial Processes and Product Use category, with data not reported for subcategories that correspond to the WIOD classification system.

Table B3: Correspondence between PRIMAP and WIOD categories.

PRIMAP category	WIOD category
Agriculture	Crop and animal production, hunting and related service activities
Energy	Electricity, gas, steam and air conditioning supply
Waste	Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services
Chemical Industry	*Manufacture of chemicals and chemical products*
Metal Industry	*Manufacture of basic metals*

In Table B3, subcategories of the PRIMAP Industrial Processes and Product Use category are shown in italics.

To summarise, our modelling includes emissions of carbon dioxide, methane, and nitrous oxide. Fluorinated gases are omitted. Overall, it is not possible to include all emission sources; however, contributions from agriculture, energy generation, chemical and metal production, and waste management are captured. In sum, our modelling accounts for 98% of the global climate footprint by gas.

B5 Health Expenditure Data

The MRIO provided the information on trade flows in the global economy, which coupled with environmental accounts gave the GHG intensity of activities in each sector of each nation or region in the WIOD database. To calculate the health care footprint, the emissions intensity data derived from the IO modelling was combined with health expenditure data for each nation and region in the WIOD model. Health expenditure data was used in place of the final demand information in WIOD to ensure alignment between sector boundaries and the definition of the health care sector from the WHO. If this had not been done, activities falling outside the WIOD definition of health care activities such as the manufacturing of pharmaceuticals would have been omitted from the foot-printing calculations.

National expenditure data was mapped onto WIOD categories using concordances between WHO and WIOD sector definitions, following [6] and [7]. Detailed descriptions of the WIOD sector definitions [8] and of the WHO expenditure categories [1] are used to ensure consistent mapping of expenditures.

Health expenditure data for each nation and region in WIOD was derived in the following manner, with efforts made to prioritize data resolution and consistency:

- For nations in the OECD, disaggregated spending data is available through the OECD health statistics database [9]. Of the 44 WIOD nations and regions, 32 are within the OECD.
- For nations not in the OECD, the WHO database provides spending data [10]. This data details spend by funding source (government, house-hold out of pocket, etc.), and was further disaggregated to match the OECD spending categories using the average spending splits in the OECD dataset. This approach was taken for 11 nations.
- For the rest-of-world region, the national health expenditure values for the 43 individual nations was subtracted from the global figure given in the WHO dataset. This value was disaggregated using the average expenditure splits from the OECD dataset.

These categories are summarised in Table B4.

Table B4: Global breakdown by available health expenditure data.

Nation grouping	Number of nations	% Global GDP	% Global population	% Global direct GHG emissions
WIOD / Inside OECD	32: **Australia** **Canada** **EU28** excluding Bulgaria, Croatia, Cyprus, Malta, Romania **Japan** **South Korea** **Mexico** **Switzerland** **Turkey** **USA**	62%	17%	32%
WIOD / Outside OECD	11[i]: **Bulgaria** **Brazil** **China** **Croatia** **Cyprus** **Indonesia** **India** **Malta** **Romania** **Russia** **Taiwan**	23%	46%	43%
Rest of World	153	15%	37%	25%

[i] Included in this category is Taiwan, which is not recognised as a nation by the UN but is included as a separate entity in the WIOD dataset.

B6 Anesthetic gases and Metered-Dose Inhalers

Anesthetic gases are powerful greenhouse gases. Anesthetic gases include nitrous oxide, as well as fluorinated gases such as Isoflurane, Sevoflurane and Desflurane. In England, the Sustainable Development Unit (SDU), part of National Health Service (NHS), identified that the total emissions from anesthetic gas use was 2.2% of the NHS footprint [11]. Anesthetic gas use therefore presents a significant component of health care's footprint which is not directly included in the MRIO-expenditure approach outlined in this report. For anesthetic nitrous oxide use, the United Nations Framework Convention on Climate Change (UNFCCC) 31 annex 1 nations report emissions data [12].

An extension to the SDU methodology was investigated for calculating the global footprint, with results compared against the UNFCCC reported data; however, there was poor agreement between the predicted and recorded emissions. Due to a lack of available global data on anesthetic use, it was decided to include the available UNFCCC numbers for annex 1 nations in the *'Anesthetic gases'* box in the main report.

For fluorinated anesthetics, such as sevoflurane, desflurane, and isoflurane, Vollmer et al. published global emissions rates in 2014, calculated through examining atmospheric concentrations of these gases [13]. While these figures are global, they are not included in our headline results to make clear a different method was used for deriving this value.

Metered-Dose Inhalers (MDIs) use hydrofluorocarbon propellants, which are GHGs. Insufficient global data on MDI usage prevented the global impact from this aspect of health care from being included in the headline results of this study. However, UNFCCC annex 1 nations report emissions from MDIs [12], and these numbers are highlighted in the *'Metered Dose Inhalers'* box in the main report.

B7 Limitations and opportunities for future research

This study aims to provide a global picture of the climate footprint of health care. As such it has used data sources and methods that prioritize completeness over resolution. The approach therefore should not be expected to give results to a similar level of detail as footprints calculated for national health care systems, health care organization or individual health care facilities.

Spending data: the SHA spending data uses a consistent definition of health care and categorization of health care providers across countries. This allows consistent comparison between countries at the expense of greater detail of spending within individual countries.

Allocation of SHA spending data into WIOD economic sectors: the SHA health care provider categories do not align directly with WIOD economic sectors; for example, HP.5 includes spending through pharmacies in hospitals that mainly serve outpatients - this spending is allocated to the WIOD sector, *Retail trade, except of motor vehicles and motorcycles*.

WIOD Detail Countries: the WIOD database gives detailed information on 43 typically high-income countries. While these countries represent significant proportions of global GDP, population and health care expenditure, lower- and middle-income countries are thus under-represented.

WIOD Rest of World category: the magnitude of the ROW category balances the MRIO table to make sure all countries' exports equal all other countries' imports. As a consequence, it also captures any irregularities in the data reporting and sector definitions between the detail countries and cannot therefore be interrogated for insights into countries not covered explicitly.

Allocation of emissions footprint to GHGP Scopes: Reporting an economic sector's footprint in GHGP Scopes requires a boundary to be drawn around the health care sector. This will include all direct emissions from the health care sector as defined by WHO, which may give a different picture when compared to a facility- or organization-based footprint.

Allocation to GHGP Scope 3 sub-categories: the MRIO method allocates emissions based on which sector of the economy the source of those emissions lies. This differs from GHGP Scope allocations which allocates emissions based on the relationship between a reporting organization and its suppliers. Allocating emissions based on a consumer / supplier relationship in an MRIO analysis requires a Structural Path Analysis to be undertaken, giving a full picture of the supply chain relationships with the model. Such an analysis was beyond the scope of this study and can be considered in subsequent stages.

Nitrous oxide as anesthetics: this is determined from data available for 31 countries under the UNFCCC reporting regime. These countries represent 15% of world population, 57% of GDP and 73% of global health care expenditure. Determining a global footprint for nitrous oxide as an anesthetic gas could come from the publication of market data for global nitrous oxide sales, or from the extension of the UNFCCC reporting regime.

Fluorinated gases as anesthetics (desflurane, sevoflurane, isoflurane): this is determined from published research on atmospheric concentrations. The global warming potential is inferred from these measurements. It can be taken as a global footprint, but due to the different method for deriving the value we report it separately.

Historical trends: this study considered emissions from health care for 2014, the latest year available for the WIOD database. Previous versions of the database and of SHA spending data offer the opportunity to consider the historical development of emissions from the sector, allowing for how the country coverage and methodology of compiling the database has changed over time.

Future projections: to understand how health care can contribute to delivering on the ambition of the Paris Climate agreement, scenarios describing possible futures and modelling how mitigation interventions might be applied to alter that future could be developed.

B8 Health sector emission reporting

The attribution of emissions to GHGP scopes, emissions sources and World Bank regions is described in this section.

B8.1 Attribution to GHGP Scopes

The Greenhouse Gas Protocol is a globally accepted method for reporting greenhouse gas emissions for organizations. The Protocol divides the emissions footprint of an organization into three broad categories. The Scope definitions are summarised in Figure B1 and interpreted into health care specific activities in

Table B5.

Figure B1: Definition of Greenhouse Gas Protocol Scopes 1, 2 and 3. ©Greenhouse Gas Protocol.

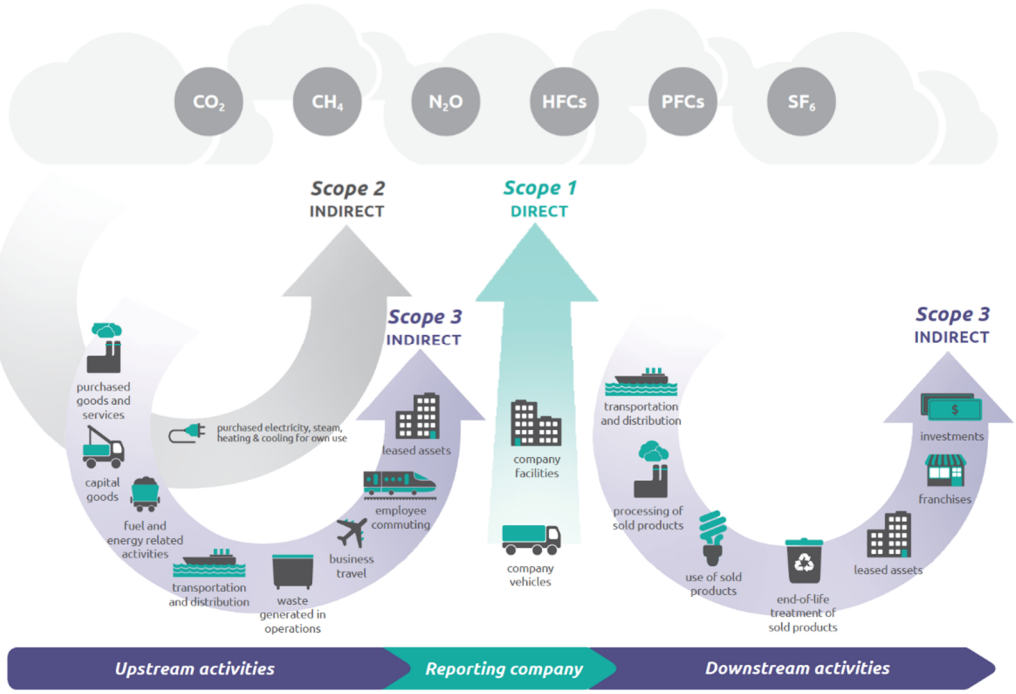


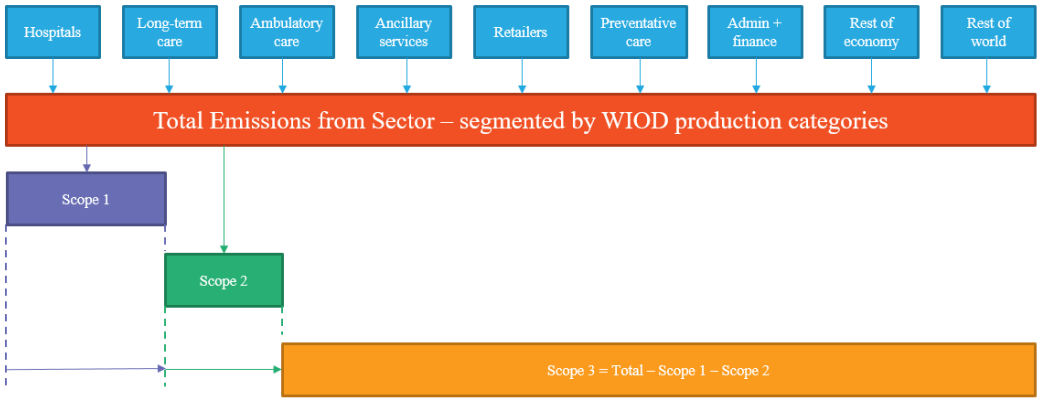
Table B5: Health sector activities grouped by GHGP protocol.

GHGP category	Activities included (WHO health care sector definition)
Scope 1	Direct emissions from health care facilities (hospitals, clinics, hospices, long term care facilities). Direct emissions from health care vehicles (ambulances, patient transport).
Scope 2	Emissions from supplied electricity, steam, heating and cooling used by Health care facilities (hospitals, clinics, hospices, long term care facilities).
Scope 3	Purchased goods and services for health care provider supply chains, e.g. pharmaceutical and medical equipment. Business travel and employee commuting for the sector. Transportation and distribution. Fuel and energy related activities. Capital goods (construction). Operational waste. Leased assets. Investments.

This study seeks to understand the footprint of the health care sector in terms of GHGP scopes and has developed an approach to reframe the outputs of the MRIO analysis in these terms. To do this a mapping was developed between the System of Health Accounts provider spending categories and Scope 1, 2 and 3 via the economic sector categories used by WIOD.

This mapping is shown in Figure B2.

Figure B2: Methodology for allocating emissions to GHGP Scope 1, 2 and 3.



Scope 1 emissions for the health care sector were calculated through multiplying the direct emissions intensity for each sector by health care expenditure in that sector in

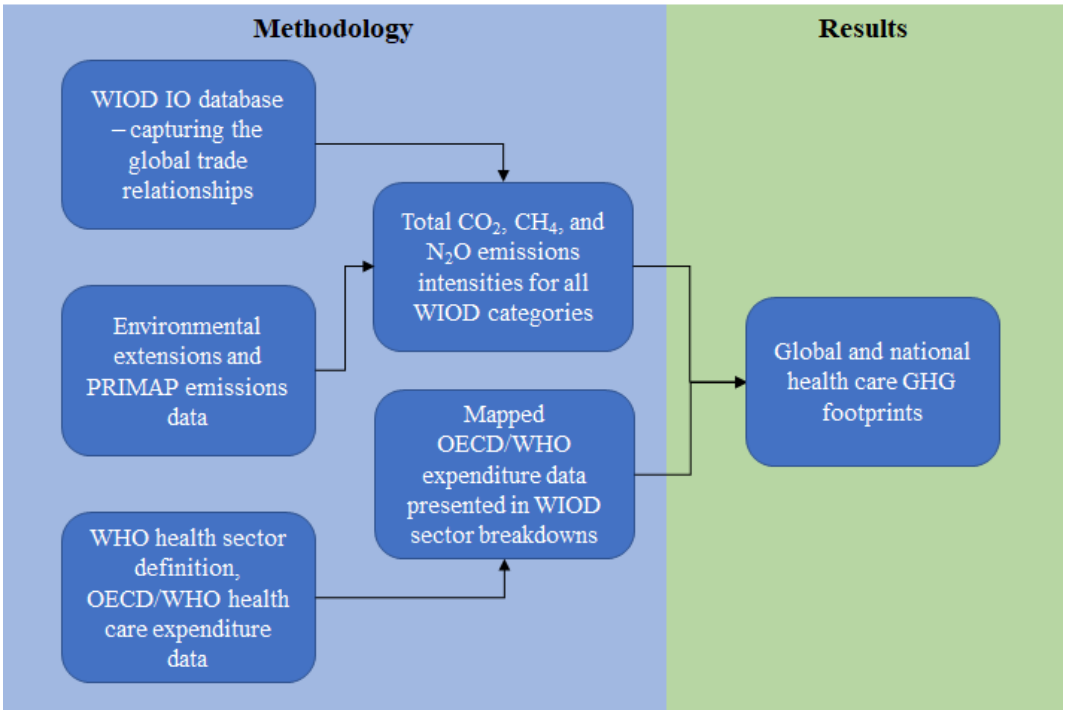
the MRIO model. Scope 2 emissions were calculated by summing direct emissions from the WIOD category, *Electricity, gas, steam and air conditioning supply*, at the first level of the health care supply chain[ii]. Once Scope 1 and Scope 2 emissions were known, Scope 3 was calculated by subtracting these values from the total.

It should be noted that given the comprehensive definition of the health care sector adopted for this study, described in Section 0, we do not expect the distribution of emissions across the Scopes to resemble what might be calculated for a health care facility or organization.

B8.2 Attribution to emissions sources

In addition to generating the full health care footprint; providing Scope 1, 2, and 3 emissions at the top level of consumption, the MRIO model enabled emissions to be tracked back to source. Emissions attributable to health care activities can be traced across sectors and borders, providing insight on the industries directly emitting GHGs upstream of health care end users.

Figure B3: Methodology summary.



In our study, it was possible to track emissions back to source WIOD category and source nation. To aid presentation of sector results, some WIOD categories are

[ii] See [19] for a detailed description of how direct emissions at each level of a supply chain can be derived.

combined into sector groupings where sectors had low individual contributions to the health care supply chain. Sector groupings are shown in Table B6.

The relationship between the WIOD category and GHGP scope breakdowns used to interrogate results is shown in Figure B4.

Figure B4: Attribution of emissions to GHGP categories and to WIOD groupings.

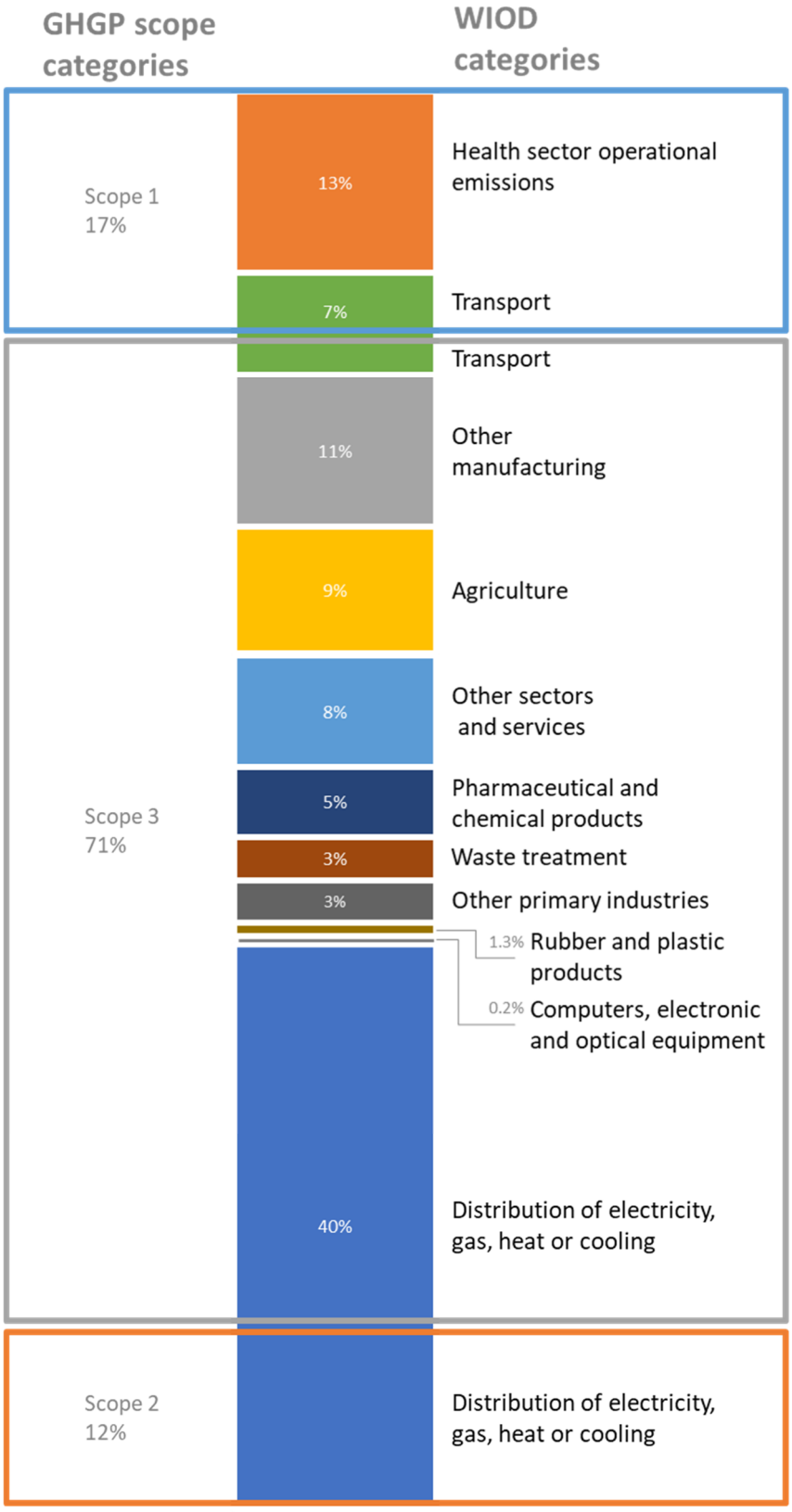


Table B6: Sector groupings constructed from WIOD categories.

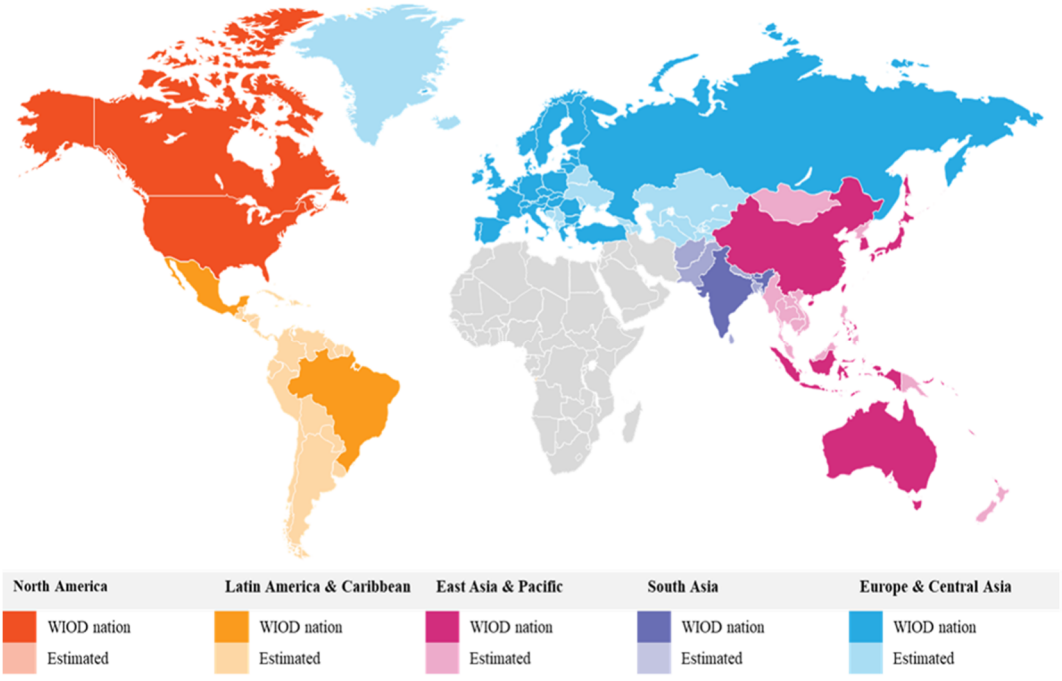
Grouping	WIOD category
Other manufacturing (including basic metals, textiles and food products)	Manufacture of food products, beverages and tobacco products. Manufacture of textiles, wearing apparel and leather products. Manufacture of wood and of products of wood and cork; manufacture of articles of straw and plaiting materials. Manufacture of paper and paper products. Manufacture of coke and refined petroleum products. Manufacture of other non-metallic mineral products. Manufacture of basic metals. Manufacture of fabricated metal products, except machinery and equipment. Manufacture of electrical equipment. Manufacture of machinery and equipment n.e.c. Manufacture of motor vehicles, trailers and semi-trailers. Manufacture of other transport equipment. Manufacture of furniture; other manufacturing.
Pharmaceutical and chemical products; direct emissions from manufacturing	Manufacture of chemicals and chemical products. Manufacture of basic pharmaceutical products and pharmaceutical preparations.
Other sectors and services	Printing and reproduction of recorded media. Repair and installation of machinery and equipment. Water collection, treatment and supply. Construction. Wholesale and retail trade and repair of motor vehicles and motorcycles. Wholesale trade, except of motor vehicles and motorcycles. Retail trade, except of motor vehicles and motorcycles. Postal and courier activities. Accommodation and food service activities. Publishing activities. Motion picture, video and television programme production, sound recording and music publishing activities. Telecommunications. Computer programming, consultancy and related activities; information service activities. Financial service activities, except insurance and pension funding. Insurance, reinsurance and pension funding, except compulsory social security Activities auxiliary to financial services and insurance activities. Real estate activities. Legal and accounting activities; activities of head offices; management consultancy activities. Architectural and engineering activities; technical testing and analysis. Scientific research and development. Advertising and market research. Other professional, scientific and technical activities; veterinary activities. Administrative and support service activities.

Grouping	WIOD category
	Public administration and defence; compulsory social security. Education. Other service activities. Activities of households as employers; undifferentiated goods- and services-producing activities of households. Activities of extraterritorial organizations and bodies.
Transport; business travel and transport in the supply chain	Land transport and transport via pipelines. Water transport. Air transport. Warehousing and support activities for transportation.
Other primary industries; mining, forestry and fishing/aquaculture	Forestry and logging. Fishing and aquaculture. Mining and quarrying.

B8.3 Regional estimates

Regional results are reported according to World Bank analytical grouping [14]. Reporting results for regions requires extrapolating results from nations with detailed WIOD data. There are no nations from the Sub-Saharan Africa or Middle East and North Africa regions reported in detail in WIOD, so results for these regions are not reported separately. Figure B5 shows the region breakdown, highlighting the nations for which WIOD results are available and those for which estimates are required.

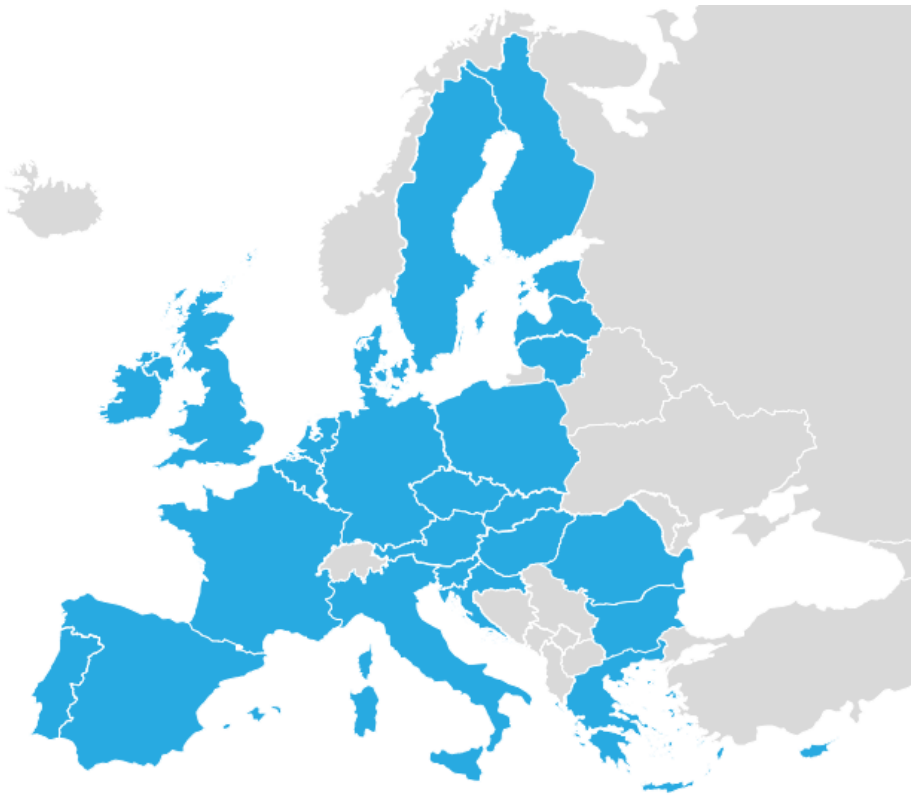
Figure B5: World Bank analytical grouping including WIOD detail nations.



In addition to the World Bank analytical groupings, regional results are reported for the European Union (EU) and the Association of South-East Asian Nations (ASEAN). Figure B6 shows the regional breakdown for ASEAN, highlighting the nations for which MRIO covers and those for which estimates are produced. Figure B7 shows EU nations, all of which are included in the MRIO modelling.

Figure B6: ASEAN nations, showing those included in WIOD detail countries.

Figure B7: EU nations[iii], all member states are included in the WIOD model.



To derive the estimate, the relationship between health care emissions and national indicators was investigated. A predictor function, using machine learning in the form of a random forest algorithm [15], was trained on model outputs to predict the health care footprint per capita for regions outside WIOD coverage.

Constructing and refining the predictor function followed an iterative process. The 43 national results were randomly separated into a training set of 39 values and test set of 4 values. At each iteration, combinations of national indicators linked to the level of development and size of health sector were used to train the predictor. Different predictor algorithms were tested for each combination, with Random Forest found to perform best. The final model used to make regional predictions was chosen based on predictor performance measured against the known values from the test set. The process identified that the predictor performed best when trained using the following national indicators:

- Human Development Index (HDI)
- Carbon dioxide emissions per capita
- Health care expenditure per capita

[iii] EU membership correct as of August 2019.

The predictor model was used to estimate health care emissions per capita for areas of the regions where national data was not available.

B9 Steering and quality assurance

To ensure project outputs are as relevant as they can be to the health care sector globally, a Technical Advisory Group from the health sector, organizations with expertise in carbon footprint measurement, and academia was convened by HCWH. This group provided comment on the methodology developed for the study and the outputs, including this white paper.

In addition, internal review was provided by health care experts within Arup and HCWH.

Throughout the modelling and validation stages of the project, the Arup team worked closely with our scientific advisor Dr Peter-Paul Pichler of the Potsdam Institute for Climate Impact Research.

Finally, the results were compared to values available in the literature.

B9.1 Validation of results

B9.1.1 Global health care emissions

Outputs from the modelling were interrogated against the literature. The most comprehensive published work in this area is that of Pichler et al. (2019), which quantified carbon dioxide emissions for the health care sectors of OECD member nations. Dr. Pichler held the role of scientific advisor for this work and our methodology largely built upon that set out in the supplementary information to their paper [7]. Our approach, however, differed in several aspects which could be expected to cause variability in model outputs:

- coverage was extended to calculate the global footprint (+25% GDP);
- methane and nitrous oxide emissions were included in the model (+25%);
- IO modelling was based of WIOD rather than Eora to facilitate comparison between countries at the economic sector-level.

Figure B8 shows the correlation between this study and the results published by Pichler et al. Nations such as China, Slovakia, India and Austria fall above the correlation line indicating our estimates are lower than Pichler et al.; whereas, for nations such as Australia, United States, Slovenia and Switzerland our model predicted higher health sector climate footprints.

Discrepancies between the results of this study and the work of Pichler et al. may have arisen due to a number of factors. There are inherent uncertainties when working with MRIO models which when comparing studies based on different underlying IO datasets can lead to variability in results. This variability is lower for larger nations where the reporting of underlying data is consistent and reliable. For

nations where capturing reliable data is more challenging due to national reporting issues, or an unusual demographic such as Luxembourg with a high GDP per capita and a small population, uncertainties will be higher as producing an MRIO necessitates more assumptions in these cases. In addition to the variation introduced into the results through the differing base datasets, expenditure data from the WHO dataset for 2014 was revised between the two studies.

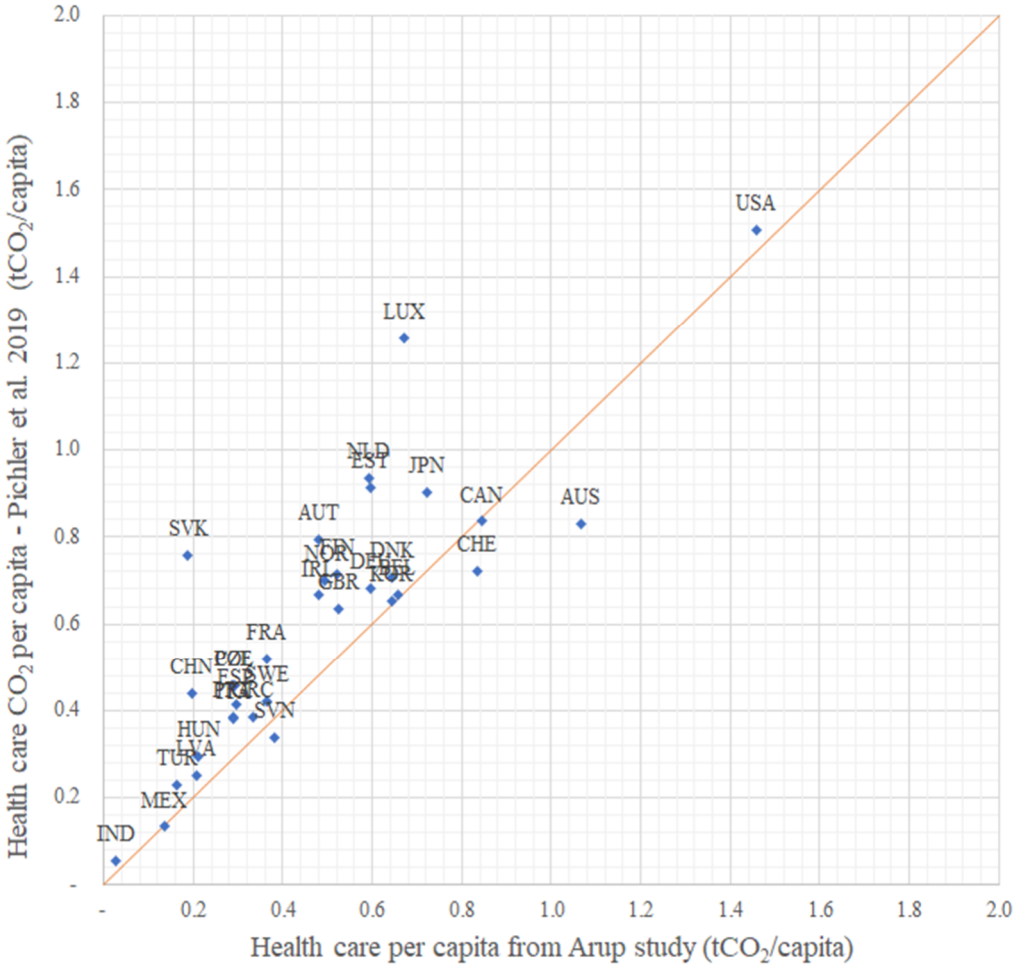
B9.1.2 Differences in results reported for China

The result presented in this paper is 45% that reported in Pichler et al. Further research is needed to fully understand the differences; however, the below points highlight some of the key differences in approach:

- different MRIO databased were used in the two studies (Eora for Pichler et al., WIOD for this paper);
- Chinese expenditure data used in this study is 85% of the pre-revision figures used by Pichler et al.;
- for nations outside the OECD we used a different approach to map World Bank health care expenditure data into national economic sectors. Specifically, we introduced an additional step in structuring the expenditure in terms of the Provider categories in the System of Health Accounts. For other countries outside the OECD a similar discrepancy between outputs exists; for example, the difference in values for India is 53%;
- spending from provider sector HP.5 *Retailers* is allocated to WIOD sector, *Retail trade, except of motor vehicles and motorcycles,* rather than *Manufacture of basic pharmaceutical products and pharmaceutical preparations.*

Taken in combination with the differing allocation of expenditure (this study disaggregated to SHA categories before mapping onto WIOD final demand sectors) and the variability from differing MRIO models this discrepancy can be accounted for.

Figure B8: Comparison between this study and Pichler et al. (carbon dioxide only) [7]



In addition to the work of Pichler et al., there are a number of health care footprints published at a national level for Australia [6], Canada [16], England [17], and the United States [18].

Table B7: Validation of results against results from existing studies.

Country	Health care emissions per capita	
	This study (tCO_2e/capita)	From literature (tCO_2e/capita)
USA	1.7	2.1 (for 2013) 1.8 (for 2007)
UK	0.7	0.5[iv] (for 2012)
Australia	1.3	1.5 (for 2015)
Canada	1.0	0.9

The differentials between the findings in this paper and previous studies are within the likely error bounds for MRIO-based climate footprint estimates.

B9.1.3 Region estimates

The estimates of regional health care emissions results are checked by comparison against the global results. The sum of the region results is 1.7 $GtCO_2e$, 0.3 $GtCO_2e$ less than the only global number. This marginally smaller number than the global total is as expected.

The difference between the sum of the regions and the global result can be used to give an indicative combined health care emissions per capita result for the regions not estimated, namely Sub-Saharan Africa and the Middle East and North Africa. Dividing this difference by the combined population of this region gives health care emissions of 0.15 tCO_2e per capita, very close to the Rest of World average reported above (0.16 tCO_2e per capita). This close result is sufficient for us to conclude that our regional estimates are consistent with the results calculated by the MRIO method.

[iv] Our study found total UK sector footprint. England represents 84% of the UK's population.

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