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The carbon footprint of Australian health care

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Summary

Background Carbon footprints stemming from health care have been found to be variable, from 3% of the total national CO_2 equivalent (CO_2e) emissions in England to 10% of the national CO_2e emissions in the USA. We aimed to measure the carbon footprint of Australia's health-care system.

Methods We did an observational economic input–output lifecycle assessment of Australia's health-care system. All expenditure data were obtained from the 15 sectors of the Australian Institute of Health and Welfare for the financial year 2014–15. The Australian Industrial Ecology Virtual Laboratory (IELab) data were used to obtain CO_2e emissions per AUS$ spent on health care.

Findings In 2014–15 Australia spent $161·6 billion on health care that led to CO_2e emissions of about 35 772 (68% CI 25 398–46 146) kilotonnes. Australia's total CO_2e emissions in 2014–15 were 494 930 kilotonnes, thus health care represented 35 772 (7%) of 494 930 kilotonnes total CO_2e emissions in Australia. The five most important sectors within health care in decreasing order of total CO_2e emissions were: public hospitals (12 295 [34%] of 35 772 kilotonnes CO_2e), private hospitals (3635 kilotonnes [10%]), other medications (3347 kilotonnes [9%]), benefit-paid drugs (3257 kilotonnes [9%]), and capital expenditure for buildings (2776 kilotonnes [8%]).

Interpretation The carbon footprint attributed to health care was 7% of Australia's total; with hospitals and pharmaceuticals the major contributors. We quantified Australian carbon footprint attributed to health care and identified health-care sectors that could be ameliorated. Our results suggest the need for carbon-efficient procedures, including greater public health measures, to lower the impact of health-care services on the environment.

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Introduction

The health effects of climate change are becoming increasingly important, with more frequent direct effects such as heat stress and fires, water inundations, and storms, and indirect effects including malnutrition from crop failures, and altered infectious disease patterns.[1] Health care itself has been shown to contribute to climate change.[2,3] In particular, hospitals are highly energy intensive, consume large amounts of resources, and produce a large amount of waste.[4] There are personal, financial, and environmental benefits from reducing our reliance on hospital-based health care and improving availability of public health. For example, personal health benefits arise from more frequent exercise, reduced obesity, the consumption of more plant-based foods, and reduced smoking and alcohol intake. Such personal benefits give rise to environmental co-benefits through reduced car use, fewer methane-producing ruminants, and fewer hospital admissions from chronic ill health.[4,5]

Environmental footprinting of health-care activities is becoming more common; particularly through the use of lifecycle assessment (LCA), a tool for quantifying environmental effects.[6–8] A carbon footprint is measured in terms of the equivalent global warming potential of CO_2 over a 100-year period. These CO_2 equivalent (CO_2e) emissions include the effects of greenhouse gases such as CH_4 and N_2O, which have emissions that are seemingly equivalent to varying CO_2e emissions. In 2008, health care in the USA contributed to 8% of that country's entire carbon footprint,[9] which was updated in 2016 to 10%,[2] whereas in 2012, England reported a more modest 4% of their CO_2e emissions being attributed to health care.[3]

In Australia, no such national carbon footprint (CO_2e emissions) study of health care has been done to date. Knowledge of the carbon footprint attributed to health care would indicate the magnitude of this concern, identifying potential hotspots that might allow a more targeted approach to reducing CO_2e emissions in a world that is producing increasing amounts of carbon. Furthermore, a top down knowledge of the total carbon footprint of Australian health care will give perspective to efforts to reduce CO_2e emissions that stem from specific activities in health care (ie, the Australian ambulance service[10] and operating theatres[8]).

We had two aims. First, we asked what the total CO_2e emissions were that arose from the actions of Australian health care in a single year (April, 2014–March, 2015) and what these were as a proportion of the entire Australian economy. Second, we asked what the CO_2e emissions were that arose from subsets of Australian health care. We examined the 15 Australian Institute of Health and Welfare (AIHW) categories including public and private hospitals, primary health care (general practitioners), medicines, and patient transport.

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Research in context

Evidence before this study

Climate change is an existential threat to planetary health. The carbon footprint attributed to health care (CO_2 emissions) is large in the USA and the UK where it has been systematically studied. The USA's health-care system contributes to about 10% of the total US carbon footprint, whereas in the UK, health care is responsible for 4% of national UK CO_2 emissions. We searched the PubMed and Engineering Village databases from Jan 1, 1990, to June 1, 2017 using the terms "health care", "greenhouse emissions", "climate change", "life cycle assessment", "input output", and "environment". All article types and languages were included. We found no evidence of other lifecycle assessments of health-care systems.

Carbon emissions are classified as direct (emanating directly from energy used within an economic sector, eg, onsite natural gas use) and indirect (electricity generation elsewhere, plastics and drug manufacture). To begin the transition towards a lower carbon economy, each nation will require data about the contributions of different economic sectors to the total CO_2 emissions. Because climate change is ultimately a health problem, knowledge about the contributions of health care to the carbon footprint is becoming more useful. Furthermore, there might be substantial differences in the carbon footprint of different health-care systems. Finally, although Australia has a relatively small population, Australia has one of the highest CO_2 emissions per person in the world.

Added value of this study

We found that the carbon footprint attributed to health care was 7% of Australia's total; that is, similar to the entire carbon emissions of all activities associated with 7% of Australians (eg, all people in the state of South Australia). Hospitals and the pharmaceutical industry were together responsible for two-thirds of the carbon footprint associated with health care in Australia. 90% of the carbon footprint stemmed from indirect CO_2 emissions due to purchases between multiple different economic sectors that fed into the health-care sector.

Implications of all of the available evidence

Our study indicates that health care contributes considerably to Australia's total carbon footprint and identifies the major contributors that could be ameliorated. Although at the federal government level, Australia has annulled a national carbon emissions trading scheme, several Australian states have programmes in place to achieve carbon neutral status by 2050. However, without data such as those we have now provided, these carbon neutral aspirations will be uncertain in outcome, and unclear in guidance. Our study begins the long path to carbon neutrality in Australian health care.

Methods

Rationale

There are two predominant approaches to environmental footprinting or lifecycle assessment (LCA): process-based LCAs and economic input–output LCAs. Process-based LCAs measure all material inputs along with all emissions to the environment of individual processes, with multiple processes combining to create a final service or product. Process-based LCAs are useful when examining small amounts of specific data,[8] but are impractical when examining the environmental effects of an entire supply chain in health care, because process-based LCAs require the selection of a system boundary. The supply chains falling within this system boundary are considered in a process LCA, whereas the rest are deemed negligible. Selection of a system boundary might result in so-called truncation errors.[11] These truncation errors can be avoided by scanning the entire upstream supply chain of a product, process, sector, or even a whole nation by use of input–output analysis.

See Online for appendix

Economic input–output LCA is a macroeconomic technique that describes the complex interdependencies between different sectors of an economy. All Organisation for Economic Co-operation and Development (OECD) countries and 27 non-member economies produce input–output tables to allow this economic analysis to occur. Economic input–output LCA takes into account all infinite upstream supply chains, without the need for the selection of a system boundary, hence providing a comprehensive picture by ensuring that both the direct (on-site) and total (direct plus indirect) effects are captured.[11,12] An example of direct CO_2e emissions would be the burning of fuel or gas at a hospital, whereas an indirect impact would be a hospital's electricity use, because that electricity was routinely generated elsewhere.

All economic activity has an environmental effect associated with it. Economic input–output LCAs assign an environmental effect to an item, process, or service via knowledge of a monetary value and its attribution to a specific economic sector. Economic input–output LCAs require a set of input–output matrices containing monetary information on the transactions between different economic sectors, and also physical data (for example on CO_2e emissions) for every sector listed in the input–output table (appendix). Input–output calculations can then be used to find both the direct and the total CO_2e emissions for all sectors (appendix).

The equation underlying the CO_2e footprint relies on a so-called stressor that equates to money spent. In the case of the footprint calculation of health care, this stressor is the expenditure data (in million Australian dollars), which is multiplied with the CO_2e emissions factor (eg, kilotonnes of CO_2e per million dollars) to yield a CO_2e emissions footprint. In this linear association, if the amount of expenditure data increases, so does the footprint.

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Input–output calculations can then be used to find both the direct and the total CO_2e emissions for all sectors (appendix). Consider the economic sector for the pharmaceutical sector, which receives inputs from other relevant sectors listed in the economy such as research and development, lawyers' and accountants' fees, business services, and travel for drug representatives. In this scenario, in addition to calculating direct CO_2e emissions for the pharmaceuticals sector, input–output analysis takes into account the monetary transactions between the pharmaceutical sectors and all the other mentioned sectors to yield a value for the total CO_2e emissions for this sector (appendix). It is important to note that such type of assessment is called footprinting, which is a well established technique for measuring both the direct and total effects (eg, CO_2e emissions) of an industry.[13,14] The advantages of economic input–output LCAs are that they are all encompassing and relatively inexpensive to do once the initial expensive data gathering has occurred, but they have increased uncertainty when moving down to the level of individual products or services.

This study did not require ethical approval from the Western Health Ethics Committee. We followed a six step procedure (appendix) for this input–output analysis, which is summarised here in five steps, using previously developed tables from the 1284 economic sectors examined by the Australian Bureau of Statistics,[15] and the consequently amalgamated 360 economic sectors by the Australian Industrial Ecology Virtual Laboratory (IELab).[16] We obtained health-care financial data for only 1 year (2014–15), as the IELab's CO_2e emissions per dollar were obtained for that year.[16]

Data collection

Importantly, the Australian Institute of Health and Welfare (AIHW) includes all government and non-government costs including private health insurance and all out of pocket costs provided by patients.[17] The AIHW lists 16 health-care expenditure categories given in the Health Expenditure Australia report. We obtained data on various health-care expenditure categories from appendix B of the Health Expenditure Australia 2014–15 report.[17] As an example of the division of such financial costs, hospital services included all pathology, radiology, and physiotherapy, as well as all labour, construction, food, paper, plastics, and medical equipment present within hospitals. Excluded from hospital services were otherwise definable AIHW categories such as pharmaceuticals, research, patient transport, and aids and appliances (even if these were occurring in hospitals). Exclusions were required to avoid counting AIHW expenditure categories more than once. Included in the health expenditure assessment were investment in equipment and facilities, though the following were excluded: expenditure that might have had a health outcome, but occurred outside the health sector; expenditure on personal activities that were not directly related to maintaining or improving personal health (ie, any form of exercise while at work); and expenditure that did not have health as the main area of benefit (ie, public and active transport; appendix). Palliative care was included in the AIHW data and was included in other services according to their location; hospitals (including hospices), or community health services in old people's homes. One of the AIHW categories was the medical expenses tax rebate, which was an accounting feature and thus did not have an environmental footprint itself and was not considered further. We also did not examine the aged care industry (ie, the care of people in hostels or nursing homes) because this was outside the domain of the AIHW data.

Data analysis

There are large amounts of monetary flows (buying and selling) between many different sectors of an economy, which can be obtained from input–output tables. Associated mathematical equations developed by Wassily Leontief have gained widespread acceptance.[18] In particular, dividing the total CO_2e emissions for a sector by its corresponding monetary output yields direct carbon emission intensities from that sector. Thereafter, multiplying the direct carbon emission intensity matrix with Leontief's inverse matrix to capture all the interactions between sectors yields total carbon emission intensities in basic economic prices. One report[19] gives a mathematical explanation for calculating direct and total carbon intensities using the Leontief input–output framework.

To calculate CO_2e emission intensities for each of the 360 sectors[16] in purchasers' prices, margins and taxes needed to be added to the basic price, following the approach of Lenzen and Dey (appendix).[20] Examples of the 360 sectors included in the input–output tables generated with IELab were leather products, motor vehicle repairs, petroleum and coal products, and rail transport.

Hereafter, when relevant, public and private hospitals have been combined and, similarly, community and public health have been combined because they are related activities occiring in the community or in broader health care). Furthermore, all dugs in the Pharmaceutical Benefits Scheme (PBS) and non-PBS pharmaceutical categories have been combined.

Matrix bridge construction

There were 360 IELab economic sectors that had to be matched with the 15 AIHW sectors with a concordance table (matrix bridge). To calculate the CO_2e emission intensities for Australian health-care expenditure categories, we constructed a matrix bridge with the 15 AIHW categories in rows and the 360 economic input–output sectors in columns, and made concordance allocations between the appropriate associated sectors. The AIHW category of unreferred medical services was in concordance with the general practice medical services

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	Explanation of expenditure items
Hospitals	
Public hospital services	Public hospital services (including pathology, radiology, and physiotherapy occurring within hospitals)
Private hospitals	Private hospital services (including pathology, radiology, and physiotherapy occurring within hospitals)
Primary health care	
PBS pharmaceuticals	All pharmaceuticals listed on the PBS
All other medications	Non-PBS pharmaceuticals
Unreferred medical services	General practice
Dental services	Dentistry (includes pathology and diagnostic services)
Community health and other	Clinics for maternal and child health, mental health, and Aboriginal and Torres Strait islanders
Public health	Includes screening programmes, disease control, immunisation, food standards, and hygiene
Other health practitioners	Services that health practitioners (other than doctors and dentists) provide, including chiropractors, optometrists, physiotherapists, and traditional (eg, Chinese) medicine
Referred medical services	
Referred medical services	Non-hospital medical services that are not classified as primary health care, and includes all care provided by specialist medical practitioners outside hospitals, including all services associated with specialist clinics that are not hospitals
Other services	
Aids and appliances	All equipment associated with rehabilitation, orthopaedics, glasses, and hearing aids that are not implanted
Patient transport services	Ambulance and patient transport services
Administration	All administration occurring within government departments of health (not including administration within hospitals)
Research and capital expenditure	
Research	Medical research, including research occurring within hospitals
Capital expenditure	Expenditure on the building of new hospitals and retrofitting or upgrading of established hospitals

PBS=Pharmaceutical Benefit Scheme.

Table 1: **Areas of expenditure for Australia's health-care sector from the Australian Institute of Health and Welfare, by category**

sector of the IELab's 360 sectors, whereas most of the other AIHW categories fell across several of the IELab's sectors. For example, the AIHW category public hospitals was matched with the following IELab sectors: hospital services (except psychiatric hospitals), psychiatric hospitals, pathology and diagnostic services, and physiotherapy services.

The concordance matrix was then converted to another matrix by proportioning; AIHW categories that were allocated to more than one economic input–output sector were converted into proportions adding up to 1 (100% of their cost), as further explained by Lenzen and colleagues (appendix).[21]

We did a second Leontief calculation[12] for the direct and indirect CO_2e emissions per dollar (the carbon intensity) of output for each of the 15 AIHW categories. Using the total monetary values of each of the 15 AIHW health-care categories multiplied by the CO_2e emissions per dollar we obtained the total carbon footprint for each sector for 2014–15 (appendix).

Statistical analysis

We did an uncertainty assessment by following the Monte Carlo approach for investigating the uncertainty of the results derived above, and present all such uncertainties as 68% CIs, which is routine in input–output LCA.[21–23] Monte Carlo methods are a broad class of computational algorithms that rely on repeated random sampling to obtain numerical results. Monte Carlo methods are used routinely in LCA and are useful when there are large numbers of inputs and when it is not pragmatic to obtain data for each of these inputs de novo. In essence, we used the standard deviation of raw input–output data for the generation of normally distributed random numbers around the input variables needed in the footprint equation (appendix).

Role of the funding source

There was no funding source for this study. All authors had full access to all of the data. All authors made the decision to submit the manuscript for publication.

Results

In 2014–15 the AIHW recorded that Australia spent AUS$161·6 billion on health-care in 15 health care sectors.[17] By use of data from IELab's[16] input–output tables, we obtained the CO_2e emission factors (CO_2e per dollar) for each of these sectors. In 2014–15 the total CO_2e emissions stemming from Australian health-care categories (table 1) were about 35 772 kilotonnes (68% CI 25 398–46 146). Given that Australia's total CO_2e emissions in 2014–15 were 494 930 kilotonnes,[16] this finding shows that health care contributed 7·2% (68% CI 5·1–9·3) of Australia's total CO_2e emissions.

Table 2 gives the expenditure data for 15 AIHW health-care expenditure categories for the decade from 2006–07 until 2014–15. The four largest financial cost categories were: public and private hospitals ($62 315 million [39%] of $161 637 million), all (PBS and non-PBS) pharmaceuticals ($19 818 million [12%]), referred (specialist) medical services ($16 942 million [10%]), and unreferred medical services ($11 031 [7%]). Hospital CO_2e emissions include all activities occurring within a hospital excluding research (even if that is in a hospital), aids and appliances, and transport to and from hospitals.

Table 3 gives the direct and total (direct plus indirect) CO_2e emissions with uncertainties given as 68% confidence intervals (one standard deviation, routine for input–output analysis),[22,23] for the 15 AIHW sectors for Australian health care. Direct CO_2e emissions per dollar are those that arose directly from each sector (electricity use was termed an indirect CO_2e emission unless it was produced on site). Pharmaceuticals had the highest direct CO_2e emissions, which could be because of drug manufacturing, which is energy intense, with the energy source often directly burnt on site. The direct CO_2e emissions attributed to health care (in kilotonnes CO_2e) were 4809 (13%) of 35 772 kilotonnes

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	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Public hospitals	32 533	34 583	36 900	39 003	40 719	43 244	45 536	45 718	46 812	48 094
Private hospitals	9503	9778	10 267	10 750	11 309	11 953	12 432	12 705	13 348	14 221
Unreferred medical services	7536	7777	8578	8655	9183	9881	10 088	10 401	10 699	11 031
Benefit-paid pharmaceuticals (PBS)	7329	7556	8145	8935	9606	9798	10 121	9949	10 047	9774
All other medications (non-PBS)	4354	5072	5539	6303	6700	7993	8657	9375	9632	10 044
Dental services	6591	6683	6823	7362	7708	8256	8735	8953	9049	9564
Community health and other	5465	5914	6529	6418	6636	7007	7694	7871	8056	8133
Other health practitioners	3865	4082	4212	4107	4370	4925	5097	5408	5405	5554
Public health	2008	2247	2726	2611	2256	2161	2434	2256	2295	2365
Referred medical services	10 893	11 503	12 332	13 109	13 685	14 096	14 913	15 510	16 297	16 942
Aids and appliances	2563	2712	2715	2902	3265	3634	3743	3870	4121	4192
Administration	3269	3102	3294	3630	3318	3381	3726	3126	3453	3643
Patient transport services	1970	2214	2406	2787	2909	3090	3238	3170	3264	3446
Research	2804	3059	3426	4424	4901	4847	5104	5186	5491	5068
Capital expenditure	5421	6126	5924	6700	6070	7788	9128	8854	9265	9566
Total costs (in AUS$ million)	106 104	112 408	119 816	127 696	132 636	142 054	150 645	152 352	157 234	161 637

AIHW Prices are expressed in terms of constant 2014–15 prices. Each year represents the financial year ending in that year (eg, 2015 is the financial year 2014–15). AIHW=Australian Institute of Health and Welfare.

Table 2: **Expenditure data (constant prices) for 15 AIHW health-care expenditure categories for Australia for 2006–15 (in million Australian dollars)**

	Total Australian expenditure (million AUS$)	Direct CO_2e emission factor (kilotonne per million AUS$)	Total CO_2e emission factor (kilotonne per million AUS$)	Direct CO_2e emissions (kilotonne)	Total CO_2e emissions (kilotonne)
Public hospitals	48 094	0·013 (0·005–0·021)	0·256 (0·181–0·331)	618 (229–1007)	12 295 (8668–15 922)
Private hospitals	14 221	0·013 (0·005–0·021)	0·256 (0·181–0·331)	183 (68–298)	3635 (2563–4707)
All other medications	10 044	0·136 (0·062–0·210)	0·333 (0·235–0·431)	1368 (629–2107)	3347 (2360–4334)
Benefit-paid pharmaceuticals	9774	0·136 (0·049–0·223)	0·333 (0·236–0·430)	1332 (486–2178)	3257 (2313–4201)
Capital expenditure (buildings)	9566	0·013 (0·004–0·022)	0·290 (0·204–0·376)	123 (39–207)	2776 (1957–3595)
Referred medical services (specialists)	16 942	0·017 (0·006–0·028)	0·128 (0·090–0·166)	288 (95–481)	2169 (1518–2820)
Community health and other	8133	0·012 (0·004–0·020)	0·227 (0·159–0·295)	96 (34–158)	1846 (1292–2400)
General practice	11 031	0·026 (0·010–0·042)	0·137 (0·095–0·179)	283 (106–460)	1509 (1041–1977)
Dental services	9564	0·013 (0·005–0·021)	0·124 (0·086–0·162)	123 (46–200)	1185 (818–1552)
Aids and appliances	4192	0·016 (0·006–0·026)	0·251 (0·177–0·325)	67 (23–111)	1054 (743–1365)
Other health practitioners	5554	0·013 (0·008–0·020)	0·139 (0·098–0·180)	71 (30–112)	774 (546–1002)
Research	5068	0·014 (0·005–0·023)	0·137 (0·095–0·179)	69 (21–117)	694 (482–906)
Administration	3643	0·031 (0·014–0·048)	0·141 (0·088–0·194)	114 (51–177)	512 (192)
Patient transport services	3446	0·013 (0·004–0·022)	0·124 (0·083–0·165)	45 (14–76)	427 (286–568)
Public health	2365	0·013 (0·004–0·022)	0·124 (0·087–0·161)	30 (10–50)	293 (205–381)
Total	161 637	..	..	4809 (3414–6204)	35 772 (25 000–45 748)

Data are n (68% CI). Data for CO_2e emissions are from the Sydney University IELab.[16] CO_2e=carbon dioxide equivalent. AIHW=Australian Institute of Health and Welfare.

Table 3: **CO_2e emissions for Australian health care by 15 AIHW expenditure categories**

total CO_2e emissions. The pharmaceutical sector had high indirect CO_2e emissions from significant interaction with multiple other economic sectors (eg, electricity, petrochemicals, and agriculture).

Hospitals, aids and appliances, community health, and capital expenditure for buildings also had high total CO_2e emission factors. High CO_2e emission factors were unsurprising for hospitals (0·26 kg CO_2e per dollar spent), which required interaction with many other economic sectors. Capital expenditure and aids and appliances sectors require interactions with sectors that have high CO_2e emissions (such as building construction and manufacturing). Community health had a high CO_2e emission factor of 0·23 kg CO_2e per dollar spent. Community health included mental health facilities that were not classified as psychiatric hospitals, thus encompassing constant care of patients requiring electricity, food, and accommodation, and included health centres in sparsely populated parts of the large Australian continent.

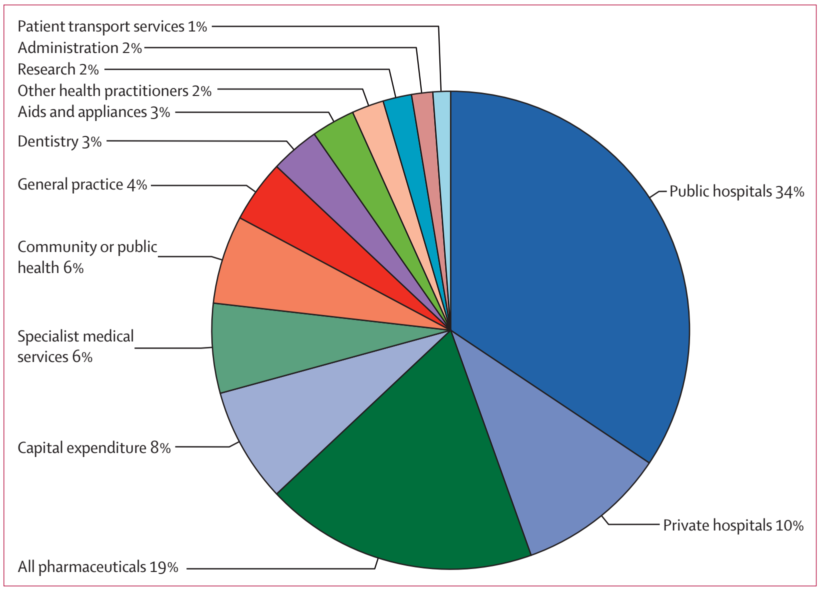

Figure: **Total and relative CO_2e emissions for 13 health-care expenditure categories**
We amalgamated the following closely associated AIHW sectors: non-PBS and PBS pharmaceuticals, and community and public health. CO_2e=carbon dioxide equivalent. AIHW=Australian Institute of Health and Welfare. PBS=Pharmaceutical Benefits Scheme.

All other health-care sectors had lower CO_2e emission factors; at least partly because they did not encompass patient admission. Patient transport services (ie, ambulances) had a low CO_2e emission factor considering the large amount of fossil fuels used for transporting patients. The actual monetary spend on fuel by patient transport services was small (<5%) compared with all other costs (labour, purchasing new vehicles, and accounting and legal services).

We identified the importance of different AIHW categories in the contribution of health-care costs to CO_2e emissions (figure); we amalgamated several associated AIHW sectors to visualise these data: non-PBS and PBS pharmaceuticals into one category for all pharmaceuticals, and community health and public health into one category. The five most important sectors in total CO_2e emissions were public hospitals (12 295 [34%] of 35 772 CO_2e emissions), private hospitals (3635 CO_2e emissions [10%]), other medications (3347 kilotonnes [9%]), benefit-paid medications (3257 kilotonnes [9%]), and capital expenditure for buildings (2776 CO_2e emissions [8%]); with referred or specialist medical services (2169 kilotonnes [6%]; table 3) also an important contributor. Most capital expenditure in health care went towards building hospitals. So, the combined carbon footprint of recurrent and capital expenditure on hospitals was greater than 50% of CO_2e emissions in the entire health-care category. General practices contributed 1509 kilotonnes (4%) to total CO_2e emissions, and patient transport 457 kilotonnes (1%). Radiology and pathology services were distributed between the hospital, specialist medical services, dentistry, and public health.

Discussion

Australia spent about AUS$161 billion on health care in 2014–15, equivalent to 9·4% of the nation's gross domestic product (GDP).[25] We did an input–output LCA, finding that the provision of such health care was 7% of Australia's entire CO_2e emissions (35 772 of 494 930 kilotonnes CO_2e emissions). As a comparator, we calculated (using the same methods as for health care) that in 2014 the carbon footprint of all Australian construction sectors (residential and non-residential building, and other construction, repair, and maintenance) was 67 599 (14%) of 494 930 kilotonnes CO_2e emissions. That is, the CO_2e emissions of health care were about half those of the construction of every single building, house, pipeline, dam, oil rig, road, and rail line in Australia in 2014–15. Similarly, the carbon footprint of Australian health care is equivalent to the total carbon footprint of all of the activities (travel, transport, housing, electricity, gas, food, entertainment, and purchases) of 7% of Australia's total population (equivalent to all people living in the state of South Australia).[26]

Hospitals (including their capital expenditure) had a carbon footprint of about half of the total for health care. Pharmaceuticals contributed to a further 20% of total CO_2e emissions, whereas specialist medical services added 6% and general practitioners added 4%. Direct CO_2e emissions from the use of fuel (gas for hot water) in health care contributed to 10% of total CO_2e emissions, whereas indirect CO_2e emissions due to purchasing from other economic sectors contributed to almost 90% of the total.

Total (public and private) health-care expenditure as a proportion of GDP was similar for Australia and England (9·4% *vs* 9·1%).[25] CO_2e emissions in Australian health care as a proportion of the total, however, were almost double England's (7% *vs* 4%). In England, private health care is responsible for about 20% of health-care expenditure.[27] The National Health Service (NHS) England's CO_2e emission data do not include private health care, although this is unlikely to increase England's CO_2e emissions from health care as a proportion of England's total to more than 4·5%. Potential reasons for such national differences include different penetration and accuracy of data gathering by the national bureaus of statistics both for financial and CO_2e emissions data and differences in health-care delivery. Furthermore, different energy sources for the national electricity mixes could account for some of the differences in the CO_2e emissions; for instance, in Australia, coal makes up 63%, gas 21%, hydroelectricity 5%, and wind 4% of national energy sources, whereas in the UK, gas makes up 30%, coal 23%, nuclear energy 21%, and wind 12% of national energy sources.[28] It is unlikely that there were differences in the methods of obtaining input-–output LCA data between Australia, the UK, and the USA, but there might have been different attributions of CO_2e emissions by economic sector by the IELab[16] in Australia compared with the UK or the USA. That is, there are different

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numbers of economic sectors for each nation and these might have had different CO_2e emissions per dollar attributed to them.

Eckelman and Sherman[2] were able to identify all environmental effects (including CO_2e emissions, pollutants, and ecotoxicity) and thus were able to calculate disability-adjusted life-years (DALYs).[2] Because our prime consideration was the climate change effects of health care we examined only CO_2e emissions, as per previous UK health-care studies.[3] It is currently impossible to obtain robust, complete national data about the quantities of many other common environmental effects for Australian economic sectors (such as water use, petrochemical and metal depletion, and terrestrial and aquatic pollution). Another limitation of our study was that we gave data for 1 year (2014–15) as the CO_2e emissions per dollar were only obtained for that year.[16] The carbon emissions of econnomic sectors vary from year to year, resulting in different carbon intensities. At the time of writing, a time-series of data on carbon emissions was not available in the IELab;[16] hence, our study only examines emissions produced in one year.

Australia's health-care statistics indicate that expenditure is rising; there is more money being spent on Australia's health-care sector every year (even when accounting for inflation). Importantly, there is a linear association between expenditure and the CO_2e emissions footprint (appendix). Thus, CO_2e emissions in Australian health care will rise with greater expenditure, unless the CO_2e emissions per dollar simultaneously fall because of greater investment in energy sources with low CO_2e emissions.

In the USA, direct CO_2e emissions in health care (from onsite hospital gas boilers) were only 3% of total CO_2e emissions,[2] whereas those in Australia were 13%. It is difficult to indicate the most likely reasons for these differences in country-specific percentages of direct CO_2e emissions, but possibilities include greater use of gas co-generation for electricity in Australia (direct CO_2e emissions), the use of different sources of electricity (coal, gas, or renewables), or simply that USA health care is buying more for each patient treated.

Previous studies of national CO_2e emissions attributed to health care have been done in the USA. In 2014, the USA spent 17·1% of GDP on health care,[25] and the resultant CO_2e emissions were 10% of the USA's total.[2] The amount spent on health care as a proportion of GDP was always more than CO_2e emissions attributed to health care as a proportion of the total. This is because health care, despite being financially expensive, has a low CO_2 emission rate per dollar compared with high CO_2-emitting sectors such as agriculture.

Pharmaceuticals contributed to 19% of Australia's, and 22% of the UK's[3] carbon footprint in the health-care sector. In the USA, prescription drugs contributed to 10% of the carbon footprint attributed to health care,[2] although it is unclear what footprint non-prescription drugs had. Further discussion about reasons for inter-country variation is speculative. Beyond hospitals, pharmaceuticals, and capital expenditure, all other health-care sectors contributed a further 30% of the total carbon footprint. Although it might seem counter-intuitive that specialist medical services or clinics had a higher carbon footprint than patient transport, almost five times as much money was spent on specialist services as on transporting patients (each dollar spent was associated with CO_2e emissions). Countries might have different numbers of economic sectors. Importantly, countries divide their economies into different numbers of economic sectors, which means that sector names in any two countries are not necessarily the same. For example, one country might divide health care into four sectors (hospitals, medicines, general practice, and others), whereas other countries might have more health-care economic sectors. This study relied on input–output tables that featured a range of industry sectors. Some input–output tables were highly aggregated with fewer sectors, whereas others were disaggregated tables with more sectors. For the case of transport, some input–output tables had a sector called transport, whereas other tables (such as the one we used in this Article) have specific details for a range of transport services, such as road transport, rail transport, air transport, and others. Regardless of which table was used for doing an input–output analysis, all transport services were included and taken into account in our study.

Climate change is an increasingly pressing health predicament.[1] Health care itself contributes to our collective carbon footprint, yet reducing this footprint is good for our health.[29] We now have the data to reduce carbon hotspots in health care. There are national Australian targets for reducing CO_2e emissions and for renewable electricity generation, yet health care itself has no carbon targets. In the UK, the Sustainable Development Unit (SDU) has been charged with efforts to reduce the health sector's carbon footprint[3] as part of a broader, nationwide economic effort to reduce CO_2e emissions, an approach that could be emulated in Australia.

A rapid reduction in CO_2e emissions is required to keep the Earth's temperature within limits for the survival of living beings; a discussion that dominated talks in the 2016 Paris Agreement.[30] Although it is clear that strategies need to be put in place for reducing the harmful effects of CO_2e emissions and for restoring the Earth's energy balance, it is also important to ensure that these strategies do not unintentionally cause harm. One of the strategies for potentially reducing CO_2e emissions is the construction of energy-efficient buildings. Making use of energy efficiency measures can decrease energy use by over 40%.[31] A rapid transition from fossil fuels, which produce high amounts of CO_2e emissions, to renewable energy technologies requires a comprehensive assessment of the new technology to minimise potential electricity grid instability and environmental burdens.[32]

Efforts to improve energy efficiency in health care, augment renewable electricity sources, and reduce unnecessary procurement costs and waste production could have financial, environmental, and social benefits.[8,33] The concept of health co-benefits[4,5] is important for tackling climate change; the use of less passive transport and more exercise,[34] less drug use, and healthier plant-based diets all have benefits for patients and have environmental co-benefits such as a smaller carbon footprint.

With bipartisan support in the UK for tackling climate change through the use of carbon targets (an 80% reduction of 1990 CO_2e emissions by 2050), the NHS SDU has led the way internationally towards health-care sustainability.[35] By systematically measuring CO_2e emissions of different health-care sectors and working through sustainable solutions with clinicians and engineers, the SDU has achieved progress in reducing CO_2e emissions, while remaining patient centred, socially responsible, and financially prudent.[3] In Australia, recent state-based legislation such as the Victorian Climate Change Act[36] and the New South Wales Climate Change Policy Framework[37] have targets for zero CO_2e emissions (including for health care) by 2050.[36] It would seem reasonable for Australians (and others elsewhere with similar targets) to seek guidance from those working within the UK's SDU to begin the transition to a low carbon health-care system.

There are also advocacy groups that are focused on reducing health's environmental footprint, both local (Doctors for the Environment Australia and the Climate and Health Alliance) and international (US Healthcare Without Harm, UK Centre for Sustainable Healthcare, and France [C2DS], the Comité pour le Développement Durable en Santé [Committee for Sustainable Health Development]). Research examining different health-care sectors, particularly through the use of LCA, would be instructive.[8] The role of public health in preventing hospital admissions in the first place will be crucial in a carbon-constrained health-care system. Competing concerns from an ageing population, whose increased use of health-care resources is likely to counteract any such savings, will need to be encompassed. All fields of medicine, medical associations, and colleges will have a role to play in reducing health-care's carbon footprint.

Contributors

AM assisted in the literature search, planned the methods, obtained most of the data, assisted in writing the manuscript, and wrote the text for the appendix. ML provided advice regarding the methods and the results, and assisted in writing the manuscript. SM assisted in the literature search, planned the methods, provided advice regarding the results, and assisted in writing the manuscript. FM conceived the study, did the literature search, planned the methods, obtained some of the data, and wrote the manuscript.

Declaration of interests

We declare no competing interests.

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