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Inclusion of Environmental Spillovers in Applied Economic Evaluations of Healthcare Products

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ABSTRACT

Objectives: Climate change and environmental factors have an impact on human health and the ecosystem. The healthcare sector is responsible for substantial environmental pollution. Most healthcare systems rely on economic evaluation to select efficient alternatives. Nevertheless, environmental spillovers of healthcare treatments are rarely considered whether it is from a cost or a health perspective. The objective of this article is to identify economic evaluations of healthcare products and guidelines that have included any environmental dimensions.

Methods: Electronic searches of 3 literature databases (PubMed, Scopus, and EMBASE) and official health agencies guidelines were conducted. Documents were considered eligible if they assessed the environmental spillovers within the economic evaluation of a healthcare product or provided any recommendations on the inclusion of environmental spillovers in the health technology assessment process.

Results: From the 3878 records identified, 62 documents were deemed eligible and 18 were published in 2021 and 2022. The environmental spillovers considered were carbon dioxide (CO_2) emissions, water or energy consumption, and waste disposal. The environmental spillovers were mainly assessed using the lifecycle assessment (LCA) approach while the economic analysis was mostly limited to costs. Only 9 documents, including the guidelines of 2 health agencies presented theoretical and practical ways to include environmental spillovers into the decision-making process.

Conclusions: There is a clear lack of methods on whether environmental spillovers should be included in health economic evaluation and how this should be done. If healthcare systems want to reduce their environment footprint, the development of methodology which integrates environmental dimensions in health technology assessment will be key.

Keywords: economic evaluation, environmental spillovers, health technology assessment, healthcare products.

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Introduction

Health and the environment are closely related. Research acknowledges the relationship between the onset of diseases; and a combination of individual characteristics and environmental, lifestyle, and socioeconomic factors.[1] Environmental factors such as pollution, climate change or extreme events impact human health and the ecosystem.[2] These factors lead to an increase in mortality and the incidence of respiratory, cardiovascular, and mental health diseases.[3] The World Health Organization considers climate change as "the single biggest health threat facing humanity"[2] and estimated, in 2018, that it will cause 250 000 premature deaths per year between 2030 and 2050.[2,4] Rapid and deep actions are therefore required across all the sectors to limit global warming up to 1.5°C and to ensure sustainable health in the long-term.[5]

Healthcare systems have a role to play in this context, as demonstrated by 1 of the 2 major commitments of the COP26 Health Programme: "Sustainable low carbon health systems."[6] According to the report of the Lancet Countdown on health and climate change,[7] 4.9% of the global greenhouse gas emissions were attributable to the healthcare sector. Eckelman and Sherman[4] estimated that the global greenhouse gas emissions emitted by the US healthcare sector, cause between 123 000 to 381 000 disability adjusted life-years (DALYs) annually. The environmental pollution of the healthcare sector contributes to increased poor health within the population; and contributes to systemic vulnerabilities and inequalities. Such pollution could be called environmental spillovers as spillovers are defined as the desirable or undesirable impacts on costs and outcomes other than those targeted by the intervention."[8] In this scoping review, we specifically focus on the undesirable environmental consequences of healthcare technologies.

Economic evaluation, especially health technology assessment (HTA) is key in guiding healthcare decision in most countries worldwide following the gold standard set by the National Institute for Health and Care Excellence.[9] Economic evaluation "requires a comparison of 2 or more alternative courses of action, while considering both the input (costs) and output (consequences) associated with each"[10] and "ensures that the value of what is gained from an activity outweighs the value of what is sacrificed."[11,12] The health gains of healthcare technologies are usually measured using health-related quality of life measures.[12,13] Nevertheless, if the environmental spillovers of the healthcare sector are responsible for poorer health or thousands of DALYs per year then the global effectiveness of healthcare technologies should not only be limited to the direct health-related quality of life gains but should also include environment-related impacts.

The objective of this review was to identify whether and how environment-related spillovers are considered when healthcare interventions are evaluated or when reimbursement decisions are formulated. Since environmental spillovers of healthcare technologies in economic evaluation is an emerging topic of research we conducted a scoping review to map what already exists.

Methods

Protocol and Registration

The study protocol was developed a priori and was followed throughout the conduct of the scoping review. The protocol was registered with Figshare (https://doi.org/10.6084/m9.figshare.17185589) on December 17, 2021.

Search Strategy

Three databases (EMBASE, PubMed and Scopus) were searched using search strategies developed with the help of an expert librarian. We chose to focus on countries from the "Europe of 12" and "G20" countries as they have identified health agencies and are more likely to be formally engaged with increased sustainable healthcare (see Appendix 1 in Supplemental Materials found at https://doi.org/10.1016/j.jval.2023.03.008). Main search terms included economic evaluation and healthcare systems of countries of interest and were combined with terms related to the environment. The full search strategy is available in Appendix 2 in Supplemental Materials found at https://doi.org/10.1016/j.jval.2023.03.008. Authors were contacted by email for full-text article when only the abstract of a conference presentation was available but the article seemed relevant. In addition, websites of the official health agencies of the 27 countries of interest were searched to identify guidelines and any documents where a framework to undertake an economic evaluation in the healthcare sector was provided. Health agencies were also contacted to provide access to guidelines if documents were unavailable on their website. Finally, the reference lists of included studies were reviewed to identify additional eligible references. The searches were undertaken between the June 1, 2021 and the July 15, 2021 and updated on September 6, 2022.

Eligibility Criteria

Eligibility criteria differed for articles identified through electronic databases and institutional documents. Any article identified through searches of the 3 electronic databases were eligible for inclusion if they were published after the year 2000. Documents published before the year 2000 were excluded because of being considered outdated. Documents were eligible if they were available in French or English, related to countries of "EU-12" or "G20," and undertook an economic evaluation along with an environmental evaluation of a healthcare technology or provided recommendations on how to consider environmental impacts of a healthcare product in an economic evaluation. Regarding health agencies, any available guidelines were eligible for inclusion if they were published after the year 2000 and mentioned environmental assessment as a part of the HTA process. There was no language restriction for the inclusion of reports from the healthcare agencies; a translation software (https://www.deepl.com/translator) was used if reports were written in an another language than English or French.

Source of Evidence Screening and Selection

EndNote X9 Software (https://endnote.com/) and Rayyan Systems Inc (https://www.rayyan.ai/) were used to collate and organize the search results from the 3 databases. On concluding the search of the listed databases, duplicates were removed. The screening and selection process was performed in 2 steps. First, all the references were screened and selected using titles and abstracts only. Second, the full texts of the included citations were retrieved and screened. The selection of documents followed a rigorous two-stage process. Two reviewers (Charlotte Desterbecq and Clément Beghuin) selected relevant documents independently and then, pooled their selection. If reviewers could not decide whether a publication should be included in the review, a third reviewer (Sandy Tubeuf) was asked to address any discrepancies. Guidelines from health agency websites were screened by a fourth reviewer (Roxane Mousset). Documents captured in the database or in list of references that were deemed relevant to the review objective, were used to cross-check the included studies.

Data Extraction

A Microsoft Excel spreadsheet was used to extract and record data from the full-text analysis. Two reviewers (CD and CB) independently completed the data extraction form for a preliminary sample of 10 publications and then compared the relevance of extracted information from the publications. Any discrepancy in extracted data were discussed by both reviewers and resolved by consensus. The documents were then equally distributed between the 2 reviewers; and data extraction forms completed for the remaining, included publications and institutional documents. Extracted data included year of publication, authors' name, publication title, research objective, study design, dataset, country(ies), type of economic evaluation, type of evaluated healthcare product, assessed environment-related elements, and their impacts on the economic evaluation. Regarding institutional documents, the different phases of the HTA process were extracted.

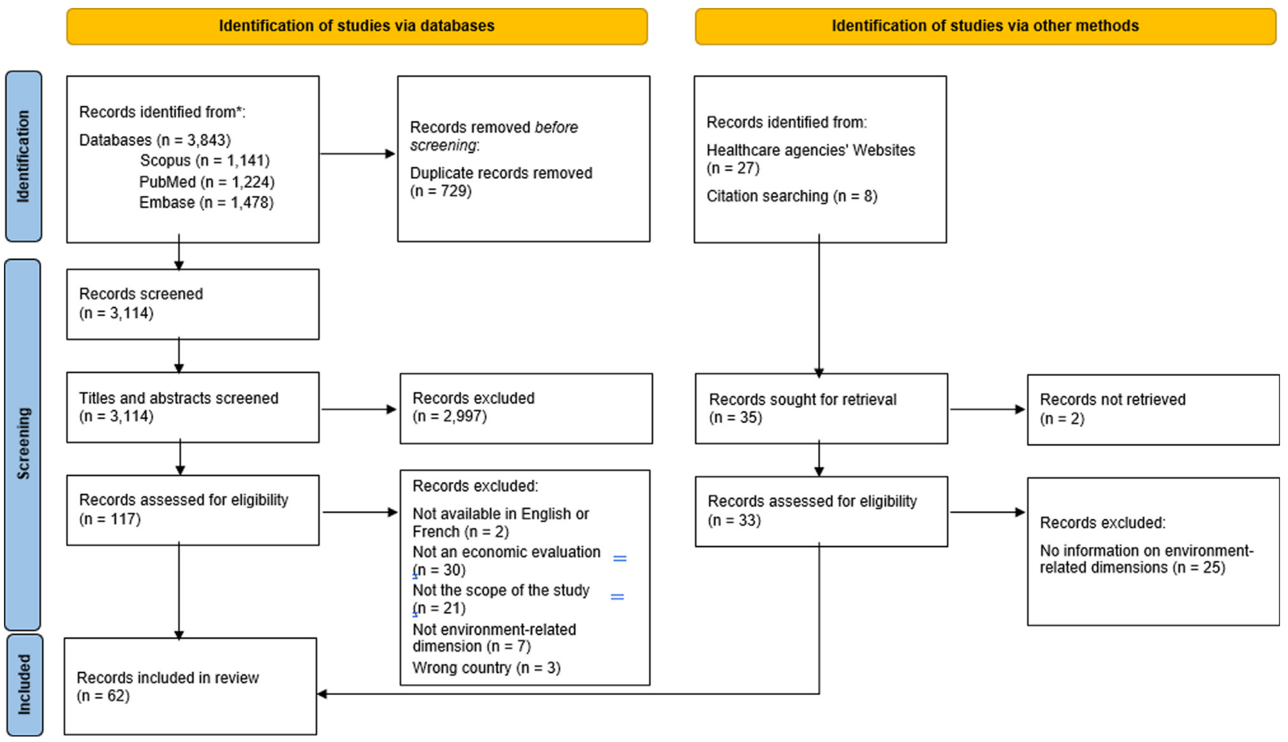
Results

Search Results

A total of 3843 citations were identified from the 3 databases; 729 duplicated citations were removed and 3114 citations were screened. After titles and abstracts screening; 2997 citations were excluded and 117 full text citations were reviewed and 63 were excluded for various reasons. Regarding healthcare agency websites, 27 documents were initially identified and citations searching led to identify 8 additional documents. From these, only 8 documents were deemed eligible for data extraction. The detailed process of articles selection is presented in a PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) chart (see Fig. 1).

Overall, a total of 62 documents were included in the scoping review.[14-75] The included documents jointly considered the environmental and economic dimensions of specific healthcare

Figure 1. Flow diagram describing the selection process of included publications.



technologies by means of case studies, international guidelines, literature reviews, and reflective articles.

Documents Characteristics

The characteristics of each included document are available in Table 1.[14-78] Documents were published between 2004 and 2022. The majority (96.7%, n = 60) were published from year 2009 onwards and 18 (29.1%) were published in years 2021 and 2022 (see Fig. 2).

According to the location mentioned in the document or the location of the corresponding authors, 17 studies were carried out in the UK, 10 in Australia, and 9 in the USA. There were also documents from England (4), Brazil (3), Ireland (3), Italy (3), Germany (2), Canada, (2) Luxembourg (1), The Netherlands (1), South Korea (1), France (1), and Spain (1). Finally, 3 studies were multicountries.

A summary of the assessed healthcare technologies, and for each technology the specified type of environmental spillovers being considered are provided in Table 2. The most investigated environmental spillover was carbon dioxide (CO_2) or CO_2 equivalent emissions (48%) (see Fig. 3).

Among the identified documents, the inclusion of environmental spillovers was undertaken in 2 alternative approaches. We defined the first approach "separate approach" as the environmental and the economic assessments of healthcare products were clearly undertaken independently from each other and the economic evaluation often was only a partial approach where costs only were considered and health gains were fully ignored, this approach included 51 articles. We defined the second approach "integrative approach" as environmental concerns were either directly included in a full economic evaluation or discussed to be integrated as a part of the HTA process, this approach included 11 articles. We presented the results from each of these approaches.

Separate Approach

Among the articles relevant to the separate approach, the different environment-related dimensions were measured as CO_2 or CO_2 equivalent emissions, water or energy consumption and waste generation.

CO_2 or CO_2 equivalent emissions

Around 40% of the included records (n = 23) considered CO_2 emissions of healthcare products. In almost 50% of those (n = 11), CO_2 emissions were calculated from converted travel distances or mileage savings resulting from the use of healthcare products and expressed as carbon footprint emissions or reductions.[23,27,28,30,31,40,43,53,56,73,75] Financial costs were estimated as cost savings associated with travel reductions such as estimated petrol and parking costs for the patient[27] (n = 7), as the costs that the patients could have spent on transport if they had a face-to-face consultation (n = 1), or as limited to the direct costs (eg, cost of electricity being used[53]) of the healthcare products (n = 2). In 1 study, a societal perspective including costs to the healthcare system, out-of-pockets costs, and cost of time-off-working were considered[75]

In 3 different articles (4.8%), Maughan et al[44-46] compared the costs to the environment of 3 different healthcare products (social prescribing service, long-acting injections, and therapeutic community) with usual care. They converted resource use of the new products including energy consumption, medical materials used, prescribed medications, number of appointments, and staff and patient travels into either carbon footprint or financial cost.

Two studies (3.2%) evaluated the change in healthcare practice: 1 study evaluated the use of low carbon alternatives to Desflurane during anaesthesia[16] and calculated cost savings as CO_2 reductions; while the other study evaluated the implementation of a medical program aiming to limit the prescription of biochemical

Table 1. Summary of the included documents in the review.

Authors and references	Year of publication	Healthcare products	Environment-related dimensions					Economic evaluation	Location
			CO_2 or CO_2 eq	Water	Energy	Waste	Other		
Adler et al[14]	2005	Disposable and reusable instruments used for laparoscopic cholecystectomy		X	X	X		CMA	Germany
Barbariol et al[15]	2021	Operating Rooms and Intensive Care Units				X		CMA	Italy
Benness and Doane[16]	2021	Anesthetic gases (Desflurane)	X					CMA	Australia
Bozorgi and Fahimnia[17]	2021	Syringe-and-needle flu vaccine with Micro array patch-enabled thermostable flu vaccine	X		X	X		CMA	Australia
Bravo, Townsend, Tulipan and Ilyas[18]	2022	Hand surgery in operating rooms				X		CMA	The USA
Burke and Stowe[19]	2015	Radiography department			X			CMA	Ireland
Canadian Agency for Drugs and Technologies in Health[20]	2020	Healthcare system and HTA	N/A	N/A	N/A	N/A	N/A	N/A	Canada
Chu et al[21]	2021	Respirator use strategies				X		CMA	The USA
Connor et al[22]	2010	Reverse osmosis (RO) units	X	X	X			CMA	The UK
Connor et al[23]	2019	Virtual ureteric colic clinic	X					CMA	The UK
Conrardy et al[24]	2010	Disposable and reusable items used in surgical services				X		CMA	The USA
Craig and Wadey[25]	2017	Air-tight system	X			X		CMA	The UK
Crema Tobara et al[26]	2019	Alcohol-based solution versus scrubbing with chlorhexidine brushes		X		X		CMA	Brazil
Croghan et al[27]	2021	Virtual urology clinics	X					CMA	Ireland
Davie et al[28]	2010	Peripatetic intravenous service	X					CMA	The UK
de Preux and Rizmie[29]	2018	Home and in-center hemodialysis	X					CUA	The UK
Dullet et al[30]	2017	Telemedicine Program	X					CMA	The USA
Filfilan et al[31]	2021	Teleconsultation in urology	X					CMA	France
Gaiser et al[32]	2004	Glass bottles on obstetric anesthesia service				X		CMA	The USA
Gatenby[33]	2011	Surgical and medical treatment of gastro-esophageal reflux	X					CMA	The UK
Hensher[34]	2020	Healthcare system and HTA	N/A	N/A	N/A	N/A	N/A	N/A	Australia
Kocaman and Galvain[35]	2022	Treatment of surgical site infection	X	X		X		BIA	England
Köhler et al[36]	2012	UV irradiation technology			X	X		CBA	Luxembourg
Koo and Jeong[37]	2015	Treatment systems of medical waste				X	Photochemical oxidant creation; Acidification potential; Human toxicity potential	CMA	South Korea

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Table 1. Continued

Authors and references	Year of publication	Healthcare products	Environment-related dimensions					Economic evaluation	Location
			CO_2 or CO_2 eq	Water	Energy	Waste	Other		
Kponee-Shovein et al[38]	2022	Inhaler choice for asthma care (DPI VS MDI)	X					CMA	England
Kwakye et al[39]	2011	Operating room and labor-delivery (surgery)				X		CMA	The USA
Lewis et al[40]	2009	Videoconferencing	X					CMA	The UK
Marsh et al[41]	2016	Two treatment regimens: an oral antidiabetic (OAD) medication, and the addition of basal insulin therapy to this OAD regimen	X					CUA	The USA
Marsh et al[42]	2016	Healthcare system and HTA	N/A	N/A	N/A	N/A	N/A	N/A	The UK
Masino et al[43]	2010	Telemedicine	X					CMA	Canada
Maughan et al[44]	2016	Social prescribing service	X					CMA	The UK
Maughan et al[45]	2016	Long-acting injections	X					CMA	The UK
Maughan et al[46]	2016	Oxfordshire therapeutic community	X					CMA	The UK
McAlister et al[47]	2021	Admissions in a Division of Medicine	X					CMA	Australia
McCarthy et al[48]	2014	Radiology department	X		X			CMA	Ireland
McGain et al[49]	2012	Reusable and single-use central venous catheter insertion kits	X	X	X	X		CMA	Australia
McGain et al[50]	2010	Reusable and single-use plastic anesthetic drug trays	X	X				CMA	Australia
McGain et al[51]	2016	Hospital steam sterilizer	X	X	X			CMA	Australia
McGain et al[52]	2017	Reusable and single-use anesthetic equipment	X	X			Eutrophication; Human, terrestrial, and marine ecotoxicity.	CMA	Australia
Miah et al[53]	2019	Virtual urology clinic	X					CMA	The UK
Miltenburger et al[54]	2018	Healthcare system and HTA	N/A	N/A	N/A	N/A	N/A	N/A	The UK
Ministry of Health of Brazil[55]	2009	Healthcare system and HTA	N/A	N/A	N/A	N/A	N/A	N/A	Brazil
Murphie et al[56]	2016	Self-fill oxygen technology	X					CMA	The UK
Ortsäter et al[57]	2019	Reusable inhalers	X			X		BIA	Denmark, Iceland, Finland, Norway, Sweden, Belgium, The Netherlands and Luxembourg
Ortsäter et al[58]	2020	Reusable inhalers	X					BIA	Germany

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Table 1. Continued

Authors and references	Year of publication	Healthcare products	Environment-related dimensions					Economic evaluation	Location
			CO_2 or CO_2 eq	Water	Energy	Waste	Other		
Polisena et al[59]	2018	Healthcare system and HTA	N/A	N/A	N/A	N/A	N/A	N/A	The USA; The UK; The USA and the UK; The USA, the UK, Germany and Belgium
Prasanna et al[60]	2011	Radiology department			X			CMA	The USA
Regan et al[61]	2018	Medical program (reducing unnecessary biochemistry samples)	X					CMA	The UK
Rizan and Bhutta[62]	2022	Hybrid vs single-use instruments in laparoscopic cholecystectomy	X				Eutrophication, Ecotoxicity, Ionising radiation	CMA	England
Rizan et al[63]	2022	Surgical scissors	X				Fine particulate matter formation, Eutrophication (freshwater and marine), Ecotoxicity (terrestrial, freshwater, marine), Toxicity (human carcinogenic, human noncarcinogenic), Resource scarcity (mineral and fossil)	CMA	England
Rouvière et al[64]	2022	Sterile medical devices in operating rooms	X			X		CMA	France
Signorini, Brugnoni, Levaggi and Garrafa[65]	2021	Lab exams / tests	X			X		CMA	Italy
Soares et al[66]	2013	Small generators: involving microwaving, autoclave, and lime disinfection	X		X			CMA	Brazil
Sowa, Fooken, McGowan and Birch[67]	2022	Reusable instruments and disposable instruments for dental care provision		X	X	X		CMA	Australia
Starup-Hansen et al[68]	2020	Inhalers	X					CEA	The UK
Tarricone, Petracca, Cucciniello and Ciani[69]	2022	Mobile medical apps	N/A	N/A	N/A	N/A	N/A	N/A	Italy
Tauber et al[70]	2019	Pharmaceutical Products in Cataract Surgery	X				Potential air pollutant emissions; Water-polluting potential eutrophication emissions.	CMA	The USA
ten Have et al[71]	2022	Inhalers	X					BIA	The Netherlands

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Table 1. Continued

Authors and references	Year of publication	Healthcare products	Environment-related dimensions					Economic evaluation	Location
			CO_2 or CO_2 eq	Water	Energy	Waste	Other		
Terlinden et al[72]	2013	Medical program (adding a cocooning strategy to a vaccinations schedule)	X					CUA	England and Wales
Vidal-Alaball et al[73]	2019	Telemedicine program	X					CMA	Spain
Wilkinson et al[74]	2019	Inhalers	X					CMA	The UK
Williams et al[75]	2022	Melanoma Surveillance	X					CMA	Australia

BIA indicates budget-impact analysis; CBA, cost-benefit analysis; CMA, cost-minimization analysis; CO_2 or CO_2 eq, carbon dioxide emissions or carbon dioxide equivalent emissions; CUA, cost-utility analysis; N/A, nonapplicable; HTA, health technology assessment; The UK, The United Kingdom; The USA, The United States of America.

tests only when deemed appropriate and measured the CO_2 emissions.[61]

Other ways to calculate CO_2 emissions were also proposed. Gatenby[33] used a top-down model of carbon to estimate CO_2 emissions and model the overall and mean cost of medication use in 2 treatments. Marsh et al[41] used a health economic model (the IMS CORE model) to predict and compare several outcomes as costs of disease and specific complications, QALY, and total and incremental CO_2 emissions of treatments for type 2 diabetes mellitus. McAlister et al[47] used a top-down methodology input-output to calculate the CO_2 emissions and the financial costs associated with the number of pathology collections in a Division of Medicine.

A total of 4 studies (6.5%), including a literature review,[68] focused on the potential CO_2 emissions and associated reductions of switching pressurized metered-dose inhalers with nonpressurized inhalers.[38,68,71,74] Kponee-Shovein et al[38] calculated the CO_2 emissions over longer term using models with alternative time horizon (50 and 10 years). They converted the emissions within each scenario into social cost of carbon (SCC) to estimate environmental costs and into DALYs to capture the health damages related to these emissions. They also calculated the annual expenses because of the use of inhalers along with a per capita cost.

Waste management

Six of the 62 (9.7%) included documents focused on waste management of healthcare products. Conrardy et al[24] estimated the reduction in waste as a consequence of the adoption of reusable products in place of disposable items; whereas Gaiser et al[32] compared glass bottle elimination and recycling within an obstetric service.

In a literature review, Kwakye et al[39] focused mainly on waste reduction and cost savings associated with greener initiatives in the surgical units. Another literature review from Bravo et al[18] focused on reduction in cost and waste of a new local anesthesia for hand.

Chu et al[21] compared several respirator strategies (disposable vs reusable with or without filter) for 6 months in the context of the COVID-19 outbreak and calculated the cost and the waste generation of each strategy.

Waste is a broad concept which encompasses drug wastage. Barbariol et al[15] measured the amount of drug wastage (medical materials and unused drugs) in 2 medical services. They also estimated the weight of preventable medical waste and the associated financial cost.

Energy consumption

Two of the 62 (3.2%) included documents focused on energy consumption of different devices (desktop, workstation displays, and ancillary electrical equipment) in radiology departments.[19,60] Burke and Stowe[19] estimated potential energy and cost savings associated with powered off devices when department closed. While Prasanna et al[60] calculated energy and cost savings when medical equipments were turned off after an 8-hour workday.

Multienvironment-related dimensions

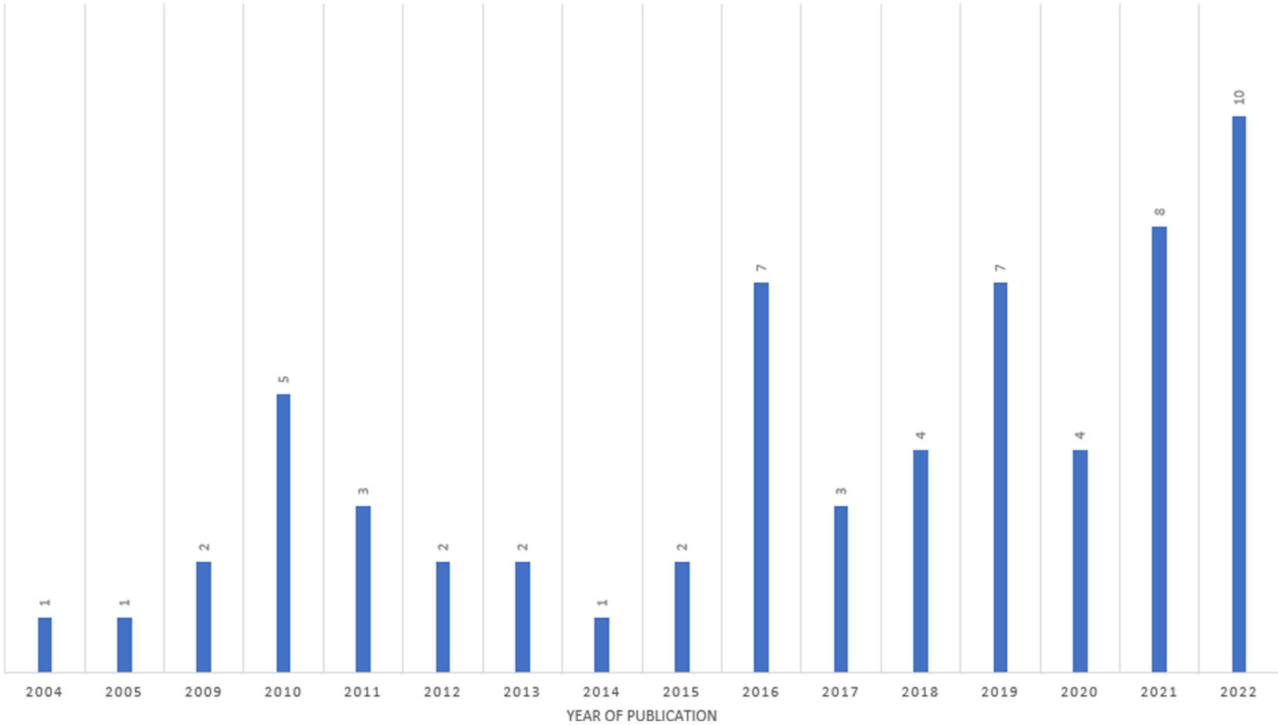
Almost a third (n = 20) of the included documents looked at several environment-related spillovers at the same time.

Three articles considered both waste disposal and energy consumption.[12,64,65] Adler et al[14] conducted a literature review into green cost savings initiatives in surgical services. Köhler et al[36] measured energy efficiency and pharmaceutical removal from wastewater of an UV irradiation technology using the LCA methodology and a cost-benefit analysis. In their study on the use of disposable versus reusable instruments in dental health practice, Sowa et al[67] used a costing model to estimate the costs at the microlevel (day-to-day) and the macro level (organization level) in 3 situations: current situation, use of reusable, and use of disposable items. They estimated the environmental impacts of waste, water, and energy consumption in these 3 situations.

Crema Tobara et al[26] estimated waste volume, water consumption, and cost savings of using alcohol solution to disinfect surgeons' hands instead of chlorhexidine brushes.

A set of publications (16.1%, n = 10) investigated both CO_2 emissions along with other environmental dimensions.[17,22,25,35,48-51,65,66] Bozorgi and Fahimnia[17] undertook a cost analysis to replace syringe-and-needle flu vaccine with microarray patch-enabled thermostable flu vaccine; they also presented benefits of this change, including the environmental benefits (reductions in energy and fuel consumption, CO_2 emissions, and waste generation). McCarthy et al[48] converted the energy consumption of medical equipment in the radiology department into CO_2 emissions, and they calculated the financial cost of the electricity use. Craig and Wadey[25] estimated the carbon footprint, waste disposable, and costs savings of an air-tight waste disposal system. Kocaman and Galvain[35] in a conference abstract presented their study on the environmental impacts (CO_2, water use, and waste generation) of treating surgical site infection at the hospital and calculated the cost of the treatment. Two different studies by McGain et al[49,50] calculated both CO_2 emissions, water consumption, and costs of reusable and disposal healthcare products such as

Figure 2. Temporal distribution of the included documents.



central venous catheter kits and anesthetic drug trays. They also estimated energy consumption related to central venous catheter kits.[49] In a third study, McGain et al[51] tested 2 policies of switching off sterilizers at different moments and estimated CO_2 emissions reductions, water and electricity savings related to each policy. Nevertheless, cost savings were only calculated for electricity and water. Signorini et al[65] compared the demand for COVID19 lab tests with the recommendations of the Internal Federation of Clinical Chemistry guidelines and the literature. They estimated the economic costs and ecological (CO_2 equivalent and waste emissions) impacts of these tests and emphasized ecological and environmental benefits when tests are done only when necessary. Soares et al[66] used the LCA method to calculate electricity and gas consumptions; and costs of 3 small generators (microwaving, autoclaving, and lime disinfection) employed for waste management.

Few articles (9.7%, n = 6) calculated the environmental impacts of healthcare devices (reusable and single anesthetic equipment[52] or single-use versus hybrid instruments[62]) or healthcare practices (treatment systems of medical waste,[37] repairing surgical scissors strategies,[63] implementation of sustainable measure targeting sterile medical devices in operating room[64] or unused pharmaceutical products in cataract surgery[70]) and classified them into various categories such as global warming (specially CO_2); eutrophication; human, terrestrial, and marine ecotoxicity, etc. LCA was used in 4 articles[52,62-64] to estimate the environmental spillovers. Each article determined the direct cost of the assessed healthcare products: 1 by a net cost analysis,[37] 1 by a Monte Carlo analysis,[52] 2 by life cycle cost analysis,[62,63] 1 using a bottom-up microcosting methodology,[64] and the last 1 used an economic input-output LCA model.[70]

Integrative Approach

The articles relevant to the integrative approach (n = 11) can be divided in 2 groups whether they provide practical or theorical ways to integrate environment-related concerns in economic evaluation.

Practical solutions

A total of 4 studies (6.5%) undertook a full economic evaluation of healthcare products (use of home vs in-center hemodialysis,[29] use of reusable inhalers,[57,58] and implementation of a medical program[72]) and included CO_2 emissions in the evaluation.[29,57,58,72] They calculated CO_2 emissions and then converted these emissions into monetary costs such as the SCC[29,57,58] or the carbon cost.[72] De Preux and Rizmie[29] and Terlinden et al[72] included this monetary value in the calculation of the incremental cost-effectiveness ratio, while Ortsäter et al[57,58] included the SCC into a budget-impact analysis over a 5-year time period perspective.

Theorical solutions

Three documents (4.8%) including a conference abstract,[34,42,54] discussed methods to consider the environmental impacts of healthcare systems in economic evaluation. Marsh et al[42] and Miltenburg et al[54] proposed to convert CO_2 emissions into monetary units such as SCC to include environment-related dimensions into cost-benefit analysis or budget-impact analysis. According to Marsh et al,[42] environmental dimensions transformed into health outcomes could be used in cost-utility analysis. The authors also suggested to utilize multicriteria decision analysis to include environment-related spillovers.[42] In his article, Hensher[34] already recommended to consider negative externalities of healthcare systems by using finding from ecological economics.[32]

Polisena et al[59] conducted a scoping review to identify existing frameworks, methods and case studies about the assessment of environmental impact of health technologies and included evidence with different foci: health economics, engineering practices, and the ecosystem. In an article on lifecycle, multidimensional

Table 2. Summary of the assessed healthcare interventions.

Healthcare products or interventions or technologies	Environment-related spillovers
Anesthetic gases	CO_2
Virtual clinics Peripatetic intravenous service Home and in-center hemodialysis Telemedicine programs Teleconsultation in urology Surgical and medical treatment of gastro-esophageal reflux Two treatments for type-2 diabetes Social prescribing service Long-acting injections Oxfordshire therapeutic community Admissions in a Division of Medicine Self-fill oxygen technology Medical programs Surgical scissors Pharmaceutical Products in Cataract Surgery Melanoma Surveillance	
Operating Rooms and Intensive Care Units	Waste
Hand surgery in operating rooms Respirator use strategies Glass bottles on obstetric anesthesia service Treatment systems of medical waste Operating room and labor-delivery (surgery)	
Alcohol-based solution versus scrubbing with chlorhexidine brushes	Waste and water
UV irradiation technology	Waste and energy
Radiology department	CO_2 and energy
Small generators: involving microwaving, autoclave, and lime disinfection	CO_2 and energy
Inhalers	CO_2 and waste
Sterile medical devices in operating rooms Laboratory examinations/tests Air-tight system	
Syringe-and-needle flu vaccine with micro array patch-enabled thermostable flu vaccine	CO_2, waste and energy
Reusable and single-use items	
Hospital steam sterilizer	CO_2, energy and water
Reverse osmosis (RO) units	
Treatment of surgical site infection	CO_2, waste and water

CO_2 indicates carbon dioxide or carbon dioxide equivalent emissions; energy, energy consumption; waste, waste management; water, water consumption.

assessment framework assessment of mobile medical apps, Tarricone et al[69] suggested to conduct an economic evaluation and to consider environmental impact as an additional outcome. Nevertheless, they did not provide any suggestion on how to do so and did not include the environmental assessment as a component of the economic evaluation.

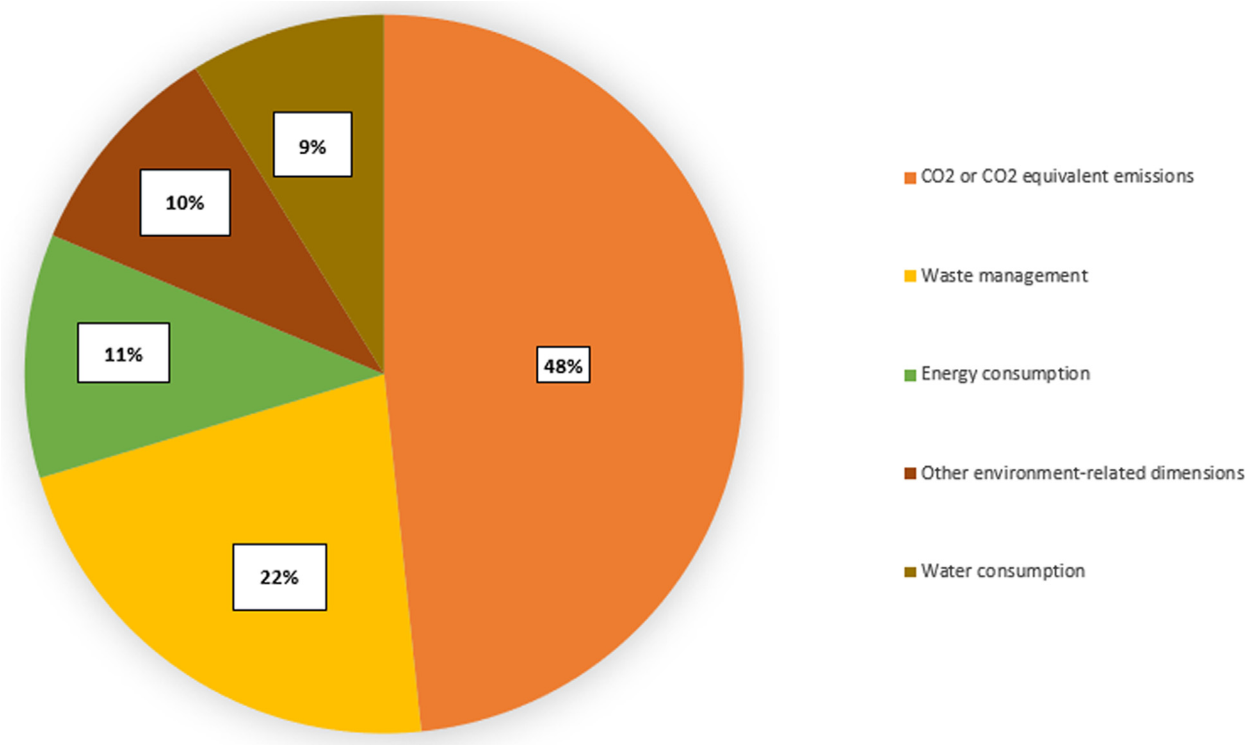
While the Brazilian and Canadian health agencies[20,55] included environmental impact as a relevant criterion in their economic evaluation guidelines, they did not provide any recommendation on how environmental spillovers should be appraised.

Discussion

This scoping review is the first attempt at studying whether the environment-related dimensions of healthcare products are included within economic evaluations. Around 30% of the included documents were published in the year 2021 and 2022. This underlines the increased awareness of environmental spillovers of healthcare systems. The majority of studies were based in the UK; this is not surprising since the National Health Service supports initiatives for greener and sustainable healthcare interventions.[76]

This review reveals that there are a number of initiatives to assess both the environmental effects and costs of healthcare products and to extend HTAs to including environment-related concerns. It also highlights that health agencies such as the Brazilian and Canadian health agencies have started to consider environment-related dimensions as a criterion within the HTA process. Still, guidance on which environmental data to include in economic evaluations and standardized methods on how to assess these environmental effects within the HTA process are lacking.

Figure 3. Percentage of each investigated environment-related spillover.



CO_2 indicates carbon dioxide.

The included publications in this scoping review differed in their ways to assess environment-related dimensions of healthcare products. The most common approach was the LCA. This method is not specific to the healthcare system but seems to be an effective alternative. Indeed, the authors who used it were able to estimate the magnitude of environmental spillovers of healthcare products. Healthcare systems are not subject to environmental standards, therefore there is no guidance on how to evaluate environment-related dimensions. Even the documents which recommended to assess the environmental impact of healthcare technologies, gave no information on how to do so.

This review highlights that CO_2 emissions were the most assessed environmental dimension. It is not clear whether other environmental dimensions were not assessed because of the complexity of estimating these effects, or because CO_2 emissions have a higher priority compared with other environmental concerns.

Only 4 documents provided solutions to including environmental impacts in the calculation of the incremental cost-effectiveness ratio within a cost-utility analysis by converting CO_2 emissions into monetary values. One study converted CO_2 emissions into DALYs but did not include it in an economic evaluation.[38] It appears therefore possible to convert environmental spillovers alternatively as a health benefit or as a cost.

Recommendations

This review highlighted a number of issues that should be clarified if environmental spillovers are included in the HTA process. Researchers must first be guided on (1) which environmental spillovers to include, (2) how environmental spillovers should be measured, especially whether they should be included as a health-related or as cost-related to avoid any double counting, and (3) finally whether environmental spillovers should form a sensitivity analysis scenario or belong to the base case scenario. The inclusion of environment-related spillovers in the HTA process will also lead to trade-offs between the efficiency of an intervention and its environmental impact. It might happen that achieving better environmental impact led to higher costs and therefore, a lower cost-effectiveness. A simple way to deal with these trade-offs could be to take inspiration from other perspectives such as the equity-efficiency trade-offs in HTA.[77,78]

In line with National Institute for Health and Care Excellence[79] and the Canada's Drug and Health Technology Agency,[80] which are in the process of establishing a list of criteria to guide the incorporation of environment-related dimensions into the decision-making process, international guidelines on which environment-related dimensions to assess and how to deal with environment-related data in economic evaluation, should be developed in the near future. It is recommended that international networks on HTA and their health agencies should collaborate to develop a joint reference case to assist in the inclusion of environmental effects in HTA.

More globally, to reduce the environment-related spillovers of the health sector, governments should implement circular economy policies in healthcare. This transition requires actions such as "recycling; reuse of products; prevention of waste; and a shift in consumption patterns"[81] but also changes in "perception and behavior from consumers to producers."[81]

Limitations

We may have missed some sources in this review for 3 reasons. First, this review was limited to documents available in English or French. Second, it only focused on EU-12 and G20 countries;

however, we can reasonably assume that if we included low-and middle-income countries, we would have found similar results since the inclusion of environmental aspects remains limited internationally and health agencies are mainly developed in high-income countries. Finally, searches only focused on the 3 major medical databases and publications available on other databases as well as gray literature was not considered.

Conclusions

Sustainable and green practices in the healthcare sector have gained more interest in recent years. This review adds to the existing work on the inclusion of environmental spillovers in economic evaluations. This research highlighted a number of publications considering both the environmental spillover of healthcare products and undertaking cost-minimization analyses. The lack of methods on how to assess environmental dimensions, which dimensions to assess and how to integrate environmental data in economic evaluations, lead to a vast heterogeneity in the methodologies. The commitment of international health agencies for sustainable healthcare is likely to lead to the development of a standardized framework to guide the inclusion of environment-related dimensions in the decision-making process.

Supplemental Material

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