Faculté de santé publique

A literature review of the environmental footprint in economics evaluation

Mémoire réalisé par
Clément BEGHUIN

Promoteur(s)
Sandy TUBEUF
Charlotte DESTERBECQ

Année académique 2021-2022
Master en sciences de la santé publique, finalité spécialisée

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Remerciement

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Le plagiat

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Contents

ABSTRACT:

Objective: This review seeks to document, through the available literature, whether and how the impact on the environment (Greenhouse gases emissions, water and energy consumption, waste production) is included in the applied economic evaluation of healthcare services and goods in the "Europe of 12".

Methods: Three literature databases (PubMed, Scopus, and EMBASE) were searched. Keywords related to economic evaluation and healthcare system have been combined with terms related to the environment. Subject titles and abstract were then analysed to select relevant articles. Eligible articles were those that provided a framework or drafted recommendations on how to include the impact on the environment of a healthcare treatment, service, or device when conducting an economic evaluation of a healthcare product where the relationship of this product with the environment is considered.

Results: From the 1226 articles identified through database, 25 were included in the results. Different environmental-related dimensions (greenhouse gases, waste, water, energy) were discovered. Common way to calculate the environment impact were also discovered, although no uniform methods were expressed.

Conclusion: Through the results, no uniform methods were found. Guidelines should be created to encourage and standardize the economic evaluation the inclusion of the environment impact.

Keywords: Literature review, Health technology assessment, Environmental footprint

1. INTRODUCTION

By now, the link between environment and health is widely known. Emissions of greenhouse gases (GHGs), fine particles, inadequate waste management or extreme events associated with climate change, in addition to causing environmental degradation, lead to an alteration in the health and well-being of the individual. However, the growth of the health sector and the environmental impact that this generates (energy consumption and waste production in particular) will directly and indirectly influence the health of individuals, which may seem contradictory given the role of the health system in improving or maintaining the health of populations. As an example, the National Health Service (NHS) in the United Kingdom emit around 25% of all carbon dioxide public sector emissions [1] with pharmaceuticals accounted for around 20% of these emissions [2].

It is therefore necessary to be able to identify the possibilities of reducing emissions and costs of the sector and thus limit their impact on health. Unfortunately, the environmental dimension is not systematically taken into account in the health technology assessment (HTA) criteria. The study by Marsh K. & al. [2] shows the interest of taking this dimension into consideration by concluding that health (individual or collective) is strongly linked to the environment. It is therefore necessary to realise the extent to which this environmental dimension is used in economic evaluations.

Therefore, this study contributes to identify the methods used in the literature to include environmental-related dimensions in regard of the economic evaluation. The main purpose of this paper is exploratory.

2. METHODS

This section presents the methods used for the search strategy, including the eligibility criteria, the screening and the data extraction and analysis.

Search strategy

Three databases (PubMed, Scopus, and EMBASE) were initially searched. Keywords related to economic evaluation (cost-benefit analysis, cost-utility analysis, cost-effectiveness analysis, cost control, heath technology assessment, benefit evaluation, medical assessment, return on investment and multiple criteria decision analysis), healthcare system (healthcare sector, health system, equipment, drug, clinical device, medical device, biomedical technology, treatment) were combined with terms related to the environment (waste management, greenhouse gas emissions, energy, environmental protection, pollution, ecosystem). Countries were already included at this point. The research equation is available in the appendix (Number 1). Documents, captured in the database search and identified as relevant to the review objective were used to cross-check the included studies and identify additional eligible references. The reference lists of included studies were also reviewed to identify additional eligible references (snowball approach).

Eligibility criteria

Eligible articles were those that included any document from databases (publications, grey literature or official health agencies reports). Documents were included if they were written in English or French and if they reported or provided a framework or a method, or drafted recommendations while they conducted an economic evaluation of a healthcare product where the relationship of this product with the environment is considered. Articles published before 2000 were excluded publication as well published outside of the Europe of 12 (Belgium, France, the Netherlands, Germany, Luxemburg, Spain, Portugal, Denmark, the United-Kingdom, Italy, Ireland and Greece). Abstracts for conferences were also included as they presented useful information.

Screening

EndNote (EndNoteX9) and Rayyan (https://www.rayyan.ai/) were used to manage the results of all searches and to facilitate the screening process. On concluding the search of the listed databases, duplicates were removed, and a preliminary sample of 5 % was drawn out of the publications and screened independently by the two reviewers (Charlotte Desterbecq and Clément Beghuin) using titles and abstracts only. This step was done to assess the convergence within the selection process for inclusion or exclusion for the review. Any disagreements were resolved through discussion to identify a consensus. The second reviewer then retrieved and screened the full texts of the included publications. Full text reading enabled us to finalise the inclusion of relevant documents.

Seven articles were not available through database or were limited to an abstract of a conference presentation. The authors of these seven articles were therefore contacted either via LinkedIn (https://fr.linkedin.com/) or directly emailed to request a copy of their paper. Three authors responded with one author responding that the paper was still in progress and the other two did not finished the paper. The rest of the four authors stayed without answer. The abstracts of the conferences were still used and included in our data extraction as some were interesting for the study.

The study selection process is presented in a Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow chart.

Data extraction

A purposely designed 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 compared the extracted information Any discrepancy in extracted data were discussed by the two reviewers and resolved by consensus. The second reviewer then proceeded to complete the data extraction forms for the publications that were included in the review.

Extracted data included year of publication, authors' name, publication title, journal, research question or study aim, study design, dataset, country(ies) of study, type of economic evaluation, type of healthcare services or good or treatments being evaluated, identified elements which have a negative impact on the environment (CO2, waste, water, energy, other), how these elements were measured, what their impacts on the economic evaluation and their costs were. CO2 was later renamed greenhouse gases (GHG) to be more inclusive.

3. RESULTS

The articles presented in this section were all considered as health technology assessment publications. In addition to that, they passed the screening to include environmental-related dimensions as already discuss.

Selection of sources of evidence

A total of 1017 articles were identified in all databases (Embase, PubMed and Scopus) while doing the literature search. After screening titles and abstracts, 964 articles were excluded **(**

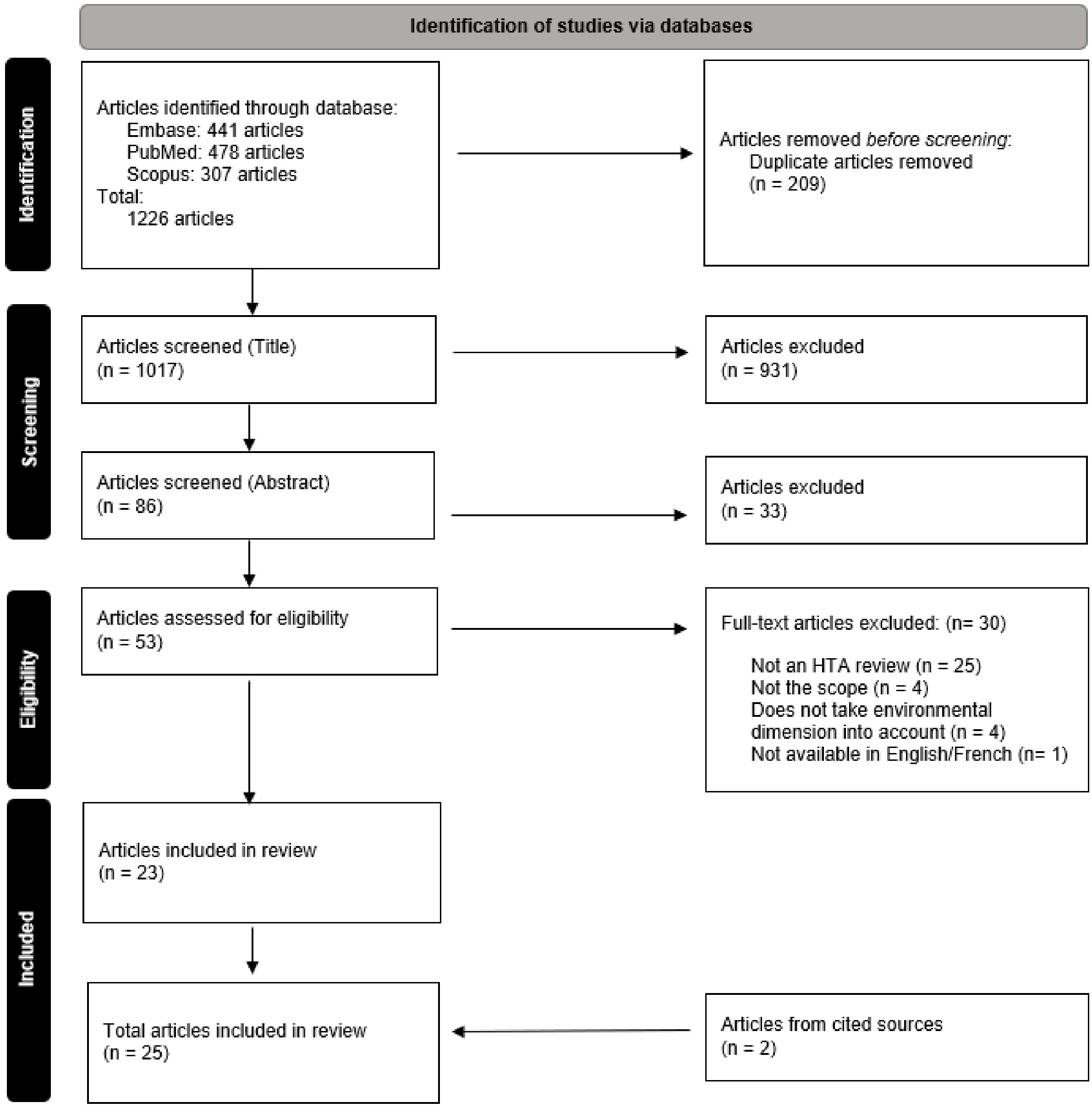

Figure *1*).

Of the remaining articles, 30 were excluded for various reasons (25 were not HTA, four were not the scope of the research, four did not included environmental dimension and one was not available in the languages included). While extracting data from the retained studies, two articles from cited sources were included as they were useful and interesting for the review and not identified through the screening process.

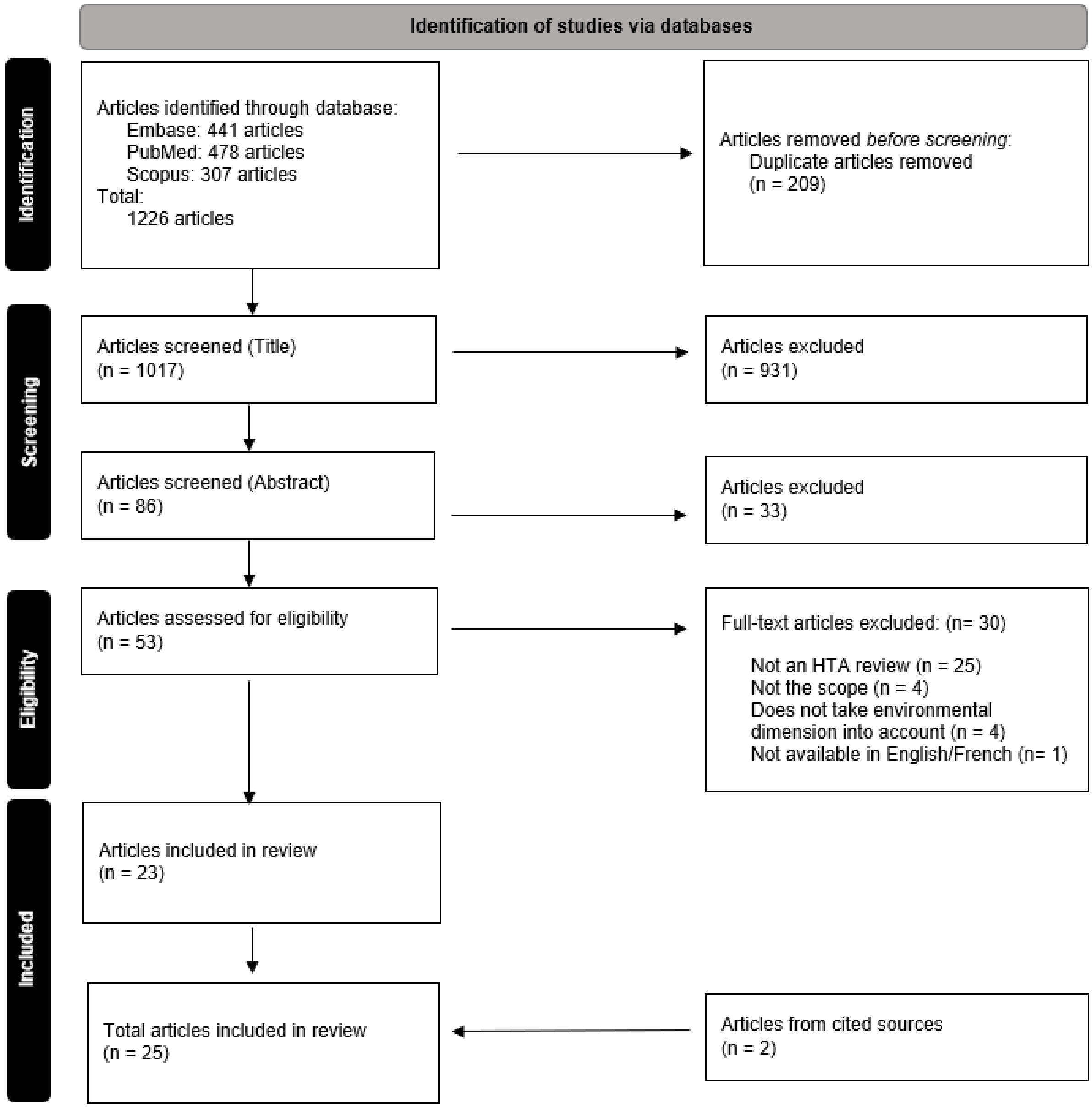

Figure 1. *Selection of included studies.*

Characteristics of sources of evidence

Countries of origin. The majority of sources of evidence (n=17) were located in the United Kingdom. Other were published in Germany (n=2), Ireland (n=2), Italy (n=1), Luxembourg (n=1), Spain (n=1) and one multi country study focused on Denmark, Iceland, Finland, Norway, Sweden, Belgium, Netherlands and Luxembourg.

Study design. The majority (n=18, xx%) of sources of evidence were case studies design followed by retrospective studies (n=3), observational studies (n=3) and one literature review.

Year of publication. Most of the articles (n=15) were published between 2016 and 2021 period follow by the 2011 to 2015 (n=6), 2006 to 2010 (n=3) and one for 2000 to 2005. (**Figure 2**). The number of publications as substantially increase every year since 2005.

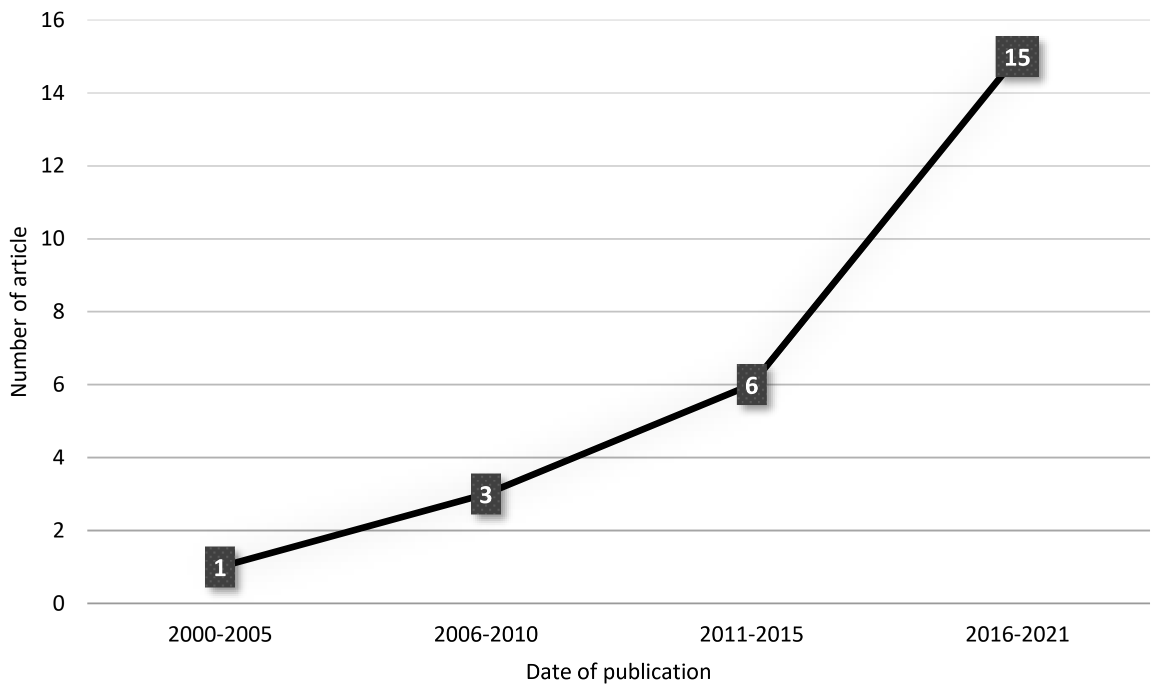

Figure 2. *Number of publications per year*

Environmental-related dimensions link to health technologies

Overview of the different environmental-related dimensions

While the data was analysed, recurrent themes and dimensions used by the authors were exposed thus creating link between the different articles (**Table 1**).

As showed in the chart (**Figure 3**), 20 (74%) articles included the greenhouse gases in their analyses (**Table 1**). Waste, water, energy and other dimensions comes after and with a significantly lower representation. Four studies included multiples dimensions in their paper. The 21 other studies included one dimension.

The type of health technologies explored in the articles varied a lot, as there is not a recurring technology that stands out. However, recurrent themes were visible. The implementation of an out of clinic/closer to patient process was present seven time ([3]; [4]; [5]; [6]; [7]; [8]; [9]) in all the 25 articles. The desire to change the type of inhaler (due to wastage and the use of greenhouse gases, GHG) came four times ([10]; [11]; [12]; [13]). The way haemodialysis is used and its production of waste was present two times ([14]; [15]). The rest of the studies presented more distinct health technologies.

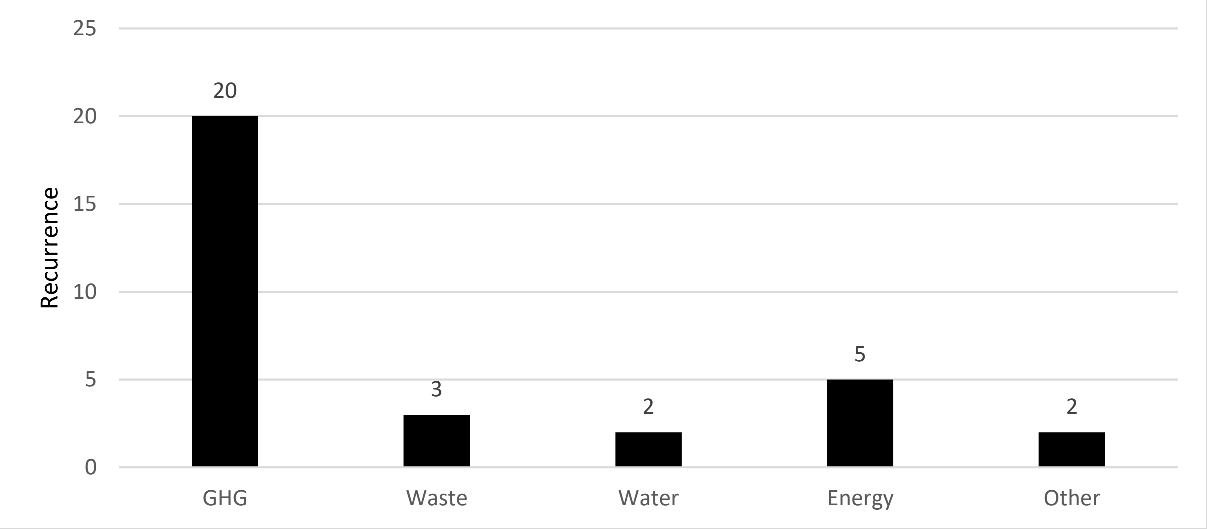

Figure 3. *Environment-related dimensions included in the articles*

Description of the different environmental-related dimensions

Greenhouse gases. The majority (74%) of source evaluated GHG emissions of the healthcare to show the impact on the environment of the health technology with the most important gases used being carbon dioxide (CO2). But it is used in two different ways, CO2 and CO2 equivalent (CO2e). The difference is that the CO2e is a metric measure used to compare the greenhouse of diverse gases to the warming impact of an amount of CO2. Six studies ([16]; [4]; [17]; [5]; [18]; [8]) used the CO2 to express the impact on the environment of their health technology. The rest of the 14 studies used the CO2e.

The study of de Preux and Rizmie [3] compared in-center (ICHD) versus home haemodialysis (HHD). The environmental impact of haemodialysis treatments was captured by their carbon footprint. Due to the fact that the CO2 is the most commonly used reference gas, they also expressed other gaseous emissions in units of CO2 equivalents. The CO2e were derived from the carbon footprint assessment conducted by Connor et al [14]. The carbon footprint estimated represented the direct and indirect greenhouse gases emissions derived from energy use, patient and staff travel and the maintenance of the haemodialysis. They then calculated the carbon footprint for their three haemodialysis modalities and expressed the results in mass. This made possible to calculate the cost per ton of CO2, also call the societal cost. This method of presenting the GHG emissions (cost per CO2e) is also used by Miltenburger et al. [19]. They believe that budget impact analyses (BIM) may include the monetary value of a more favorable PCF using a social cost of carbon. Ortsäter et al. ([10]

[11]) also used the societal cost in their studies. They performed an economic evaluation that incorporates the ecological impact of adopting RESPIMAT re-usable (a re-usable inhaler) into the healthcare system. The lifecycle product carbon footprint (PCF) measured as kilos of CO2e was calculated for the inhaler for different posology. The number of inhaler devices saved was calculated for different scenarios and then transformed in mass (tons) of CO2e. After that, they calculated the societal cost, the cost per CO2e. Only these studies showed the cost per CO2e of their health technology. Although they did not used the societal cost, Starup-Hansen et al. [12] also worked on the problematic of inhaler with their review. They took the impact of metered-dose inhalers (MDIs), using higher global warming potential gases compared to dry powder inhalers (DPIs) which do not require propellant. They review the estimated the potential CO2e saving with the entire life cycle of the inhalers.

The other studies that calculated the CO2e didn’t go further once they had the results in mass. In both of their study, Maughan et al ([6]; [7]) made retrospective research on the implementation of an out of clinic process for patient with mental health. The purpose of the implantation of theses out of clinic process is to reduces cost and carbon footprint by reducing travel time/distance and reducing clinical activities. The data collection was made respectfully on four and three years. The carbon footprint (mainly the footprint of the travel distance and clinical activities) was estimated using a bottom-up approach. This approach measured direct resource use in the health technology and used carbon conversion factors to obtain results in mass of CO2e. The staff and patient travel were measured using surveys. The footprint of each resource type was then summed to obtain total of carbon footprint in CO2e. Connor et al [3] also expressed the GHG saving by reducing travel distance in CO2e. They calculated the range of carbon footprint (tons) due to travel avoidance depending on mode of transport implanting a virtual clinic for the ureteric colic. The carbon footprint was generated on the patient mode of transport. A third study also calculated the CO2e of the avoiding. Murphie et al. [9] estimated the reduction in travel with the HomeFill ambulatory oxygen system compared to the ambulatory oxygen cylinder delivery model. The HomeFill system requires less visits per year to service the equipment. Reduction was showed in miles and the estimated carbon emission reduction for the HomeFill system was in tonnes of equivalent carbon dioxide.

Connor et al. [14] used a life-cycle conversion factor to transform the waste of water and the consumption of electricity in dialysis in CO2e. This result showed the direct link between the environmental dimensions and the health technology (water waste and electricity consumption were transpose in CO2e). This facilitated the vision of impact of the health technology and made possible further comparison. McCarthy et al. [20] also transform the electricity consumption in CO2e while they evaluated the waste of power in radiology department. The purpose was to implement new process to reduce the devices left on power over night. They estimated the greenhouse emissions in carbon dioxide equivalent for each device left on power over night in metric tons. Results were estimated for a year.

Terlinden et al. [21] made a different used of the CO2e. Their hypothesis is that by preventing disease, the cost expressed in CO2e of pertussis vaccination might be offset by avoided events like doctors' visits, hospital bed stays or medication. They examined the CO2e savings of a pertussis booster vaccine dose for cocooning in England and Wales. Cradle to gate (from raw material extraction, to manufacturing process, to disposal) carbon footprint was calculated for each dose of vaccine. A mass of CO2e per dose was calculated. Wilkinson et al. [10] made similar used with the mass of CO2e by calculated it per inhaler. They analysed the impact on greenhouse gas emissions and drug costs of switching metered-dose inhalers (MDIs) to low global warming potential (GWP) inhalers. Carbon footprint was estimated by multiplying the estimated weight of hydrofluoroalkane (HFA) propellant (gas) by its global warming potential. They also estimated the CO2e save per year for different scenario like replacing a percentage of MDIs to low GWP inhaler.

Vidal-Alaball et al. [8], while evaluated the effect of a telemedicine program, made a distinction between the CO2 and different GHG (Carbon monoxide, Nitric Oxide and Sulphur dioxide). Is retrospective study used administrative data to calculate the effect of a reduce distance travelled by patient. They found reduction in the emissions of pollutants in tonnes of carbon dioxide, kg of carbon monoxide, kg of nitric oxide and kg of sulphur dioxide. There are the only one to separate the GHG and not convert them into CO2e.

In the other studies that taken the GHG into account, the CO2 was the only gas showed. Two other studies ([4]; [5]) focused on the CO2 save by reducing the travel of patient but only with the CO2. For all of them, the CO2 saved by reducing travel distance was estimated using surveys and governmental calculator. They both calculated the mass of CO2 saving per averaged trip distance and extrapolated to months and year. The last three studies calculated the CO2 for each of their research purpose. Back et al. [16] calculated the CO2 saving by reducing the flow of gas during intravenous anaesthesia. They also considered the difference in the carbon intensity due to difference electricity generation by country. The paper of Gatenby et al [17] examined the difference in carbon footprint between the surgical and medical treatment of gastroesophageal reflux using a top-down model of carbon emissions. The results were given in mass (kg) per year for both the medical arm and the surgical arm of the treatment. Regan et al. [8] described a quality improvement project (QIP) designed to reduce unnecessary biochemistry samples requested on a paediatric cardiology ward in Great Ormond Street Hospital. Results of carbon dioxide saving were showed in tonnes per year. The result of these last articles was used in each paper to compare a product/process using the cost and the CO2 emission.

Energy. The energy is the second most used dimension (20%) to show the impact of health technologies on the environment. Every study measured the electricity consumption in kWh.

Adler et al. [22] calculated the energy consumption (kWh) while they compared disposable and reusable instruments used for laparoscopic cholecystectomy. The energy used was the one use by the cleaning process of the reusable instrument (the energy from the production of the disposable instrument was not calculated). Connor et al. [14] (already discussed in the GHG section) measured the power consumption of the salvage pump from a dialysis unit in a daily use basis. The result (kWh) was then extrapolated to a year. The purpose was to show the cost saving of by adopting new practice. Köhler et al. [23] investigated and assessed the UV irradiation technology as a membrane bioreactor (MBR) post-treatment (consisting of a comparison between to UV lamps). The efficiency of the MBR has been determined by a seven and a five-day measurement campaign in which typical wastewater compounds and pharmaceuticals were analysed, both observing the influent and the effluent of the MBR treatment. Subsequently, several batch experiments were conducted to evaluate the UV treatment. They also estimated the energy need for the lamps.

Burke and Stowe [24] measured the energy saving (kWh) in the radiology department when the equipment was left on power through night and weekend. This was done by doing surveys (with the staff) and direct measurement or documentation information. Energy saving of adopting a new process (systematically turning off equipment) was calculated. With the same idea, McCarthy [20] (already discussed in the GHG section) calculated the energy consumption of leaving devices on power over night in kWh. Figures were extrapolated to give an annual power consumption when the devices were not in active use.

Waste. The study of Adler et al. [22] (already discussed in the energy section) showed the volume of waste (kg) generated by disposable instruments including the weight of the packing material (waste from reusable was marginal) over reusable instruments. The disposal cost for household waste generated was also calculated. The volume of waste from the reusable instrument was considered to be marginal. Barbariol et al. [25] calculated the waste using unit (of syringes) and kg while they monitored the actual amount of drug wastage in the operating rooms (ORs) and intensive care units (ICUs). Total drug waste (L) during the study was registered an extrapolated to obtain an annual estimation. Ortsâter et al. [10] estimated the decrease of inhaler in both of their studies where they created scenarios of the implementation of the RESPIMAT re-usable inhaler. They estimated the decrease of the number of inhalers used in comparison to a scenario without RESPIMAT re-usable.

Water. Adler et al. [22] (already discussed in the energy and waste section) calculated the volume of water (m^3) as well as the mass of the steam (kg) needed to clean reusable instrument over disposable. Connor et al. [14] (already discussed in the GHG section) measured the volume (l) of wastewater and extrapolate it to a year of dialyses using flow meters. the purpose was to calculate the price of the water rates and find a cost per litres in dialysis.

Other. Barbariol et al. [25] (already discussed in the waste section) was the only study that considered the pollution on the environment (water here). They examine the toxicity of drug waste in aquatic environment to concluded that Propofol (medication that results in a decreased level of consciousness and a lack of memory) is “highly toxic to aquatic organisms, has a high potential for bioaccumulation, and a high soil mobility. It is not biodegradable in water or under anaerobic conditions and requires incineration for its complete destruction”. They showed the total (l) of Propofol waste during the study period and estimated it to a year.

Table 1. Study Characteristics

Year of the publication	Authors	Type of healthcare devices, services, systems or programs in the study	Environment-related dimensions included					How were the cost calculated with the environment?	How elements were measured
			Green House Gases	Waste	Water	Energy	Other		
2005	Alder S. et al. [22]	Disposable and reusable instruments used for laparoscopic cholecystectomy	/	Volume of waste in mass	Waste of water in mass	Consumption in kWh	/	Separately	Measured and estimated
2021	Back. M. et al. [16]	Fresh gas flow during total intravenous anesthesia	CO2 in mass	/	/	/	/	Separately	Measured for CO2 and Cost were estimated with linear regression of UK cost data
2021	Barbariol, F. et al. [25]	Drug wastage in anesthesia and emergency	/	In unit of syringe and volume of mass	/	/	Aquatic toxicity drug, volume in mass	Separately	Measured
2014	Burke, N. P. and Stowe, J. [24]	Energy efficiency in radiography department	/	/	/	Consumption in kWh	/	Together (cost per kWh)	Surveys and measured
2010	Connor, A. et al. [14]	Water waste in dialyses	CO2e in mass	/	Waste of water in mass	Consumption in kWh	/	Separately	Water and energy were measurred Lice-cycle conversion factor to transfrom mains water and electricity in CO2e
2019	Connor, M. J. et al. [3]	Implementation of a virtual clinic for the ureteric colic	CO2e in mass	/	/	/	/	Separately	Cost-outcomes analysis using NHS data CO2e was estimated
2010	Davie, M. et al. [4]	Close to patient peripatetic intravenous service (PIVS) for delivery of specialist osteoporosis care	CO2 in mass	/	/	/	/	Separately	Cost and CO2 was estimated
2018	de Preux, L. and Rizmie, D [15]	The differences between in-center versus home haemodialysis	Cost per ton of CO2e	/	/	/	/	Together (cost per CO2e)	Cost were estimated with a cost model. Cost of CO2e wer estimated with UK carbon valuation QALY were used
2011	Gatenby, P. A. C. [17]	Difference between surgical and medical treatment of gastro-oesophageal reflux	CO2 in mass	/	/	/	/	Separately	Estimation of cost Estimation of CO2 with a top-down model (data from REFLUX trial HTA)
2012	Köhler, C. et al. [23]	Elimination of pharmaceutical in wastewater treatment in hospital	/	/	/	Consumption in kWh	/	Together (cost benefit of energy efficiency)	Electricity was measured using life cycle assessment
2009	Lewis, D. et al. [5]	The use of videoconferencing for virtual meetings between the multidisciplinary teams	CO2 in mass	/	/	/	/	Together (cost per trip/CO2 per trip)	Surveys and estimated with UK calculator for CO2
2015	Marsh, K. et al. [2]	N/A	/	/	/	/	Environmental evidence base	N/A	N/A

Table 1. Continued

Year of the publication	Authors	Type of healthcare devices, services, systems or programs in the study	Environment-related dimensions included					How were the cost calculated with the environment?	How were elements measured
			Green House Gases	Waste	Water	Energy	Other		
2016	Maughan, D. et al. [6]	Therapeutic communities (TCs) to people with personality disorder difference with usual treatment	CO2e in mass	/	/	/	/	Together (cost/CO2e per appoeintment)	Retrospective (surveys) on four years CO2e estimated with bottom-up approach and conversion factor for cost
2016	Maughan, D. L. et al. [7]	Social prescribing services for mental healthcare difference with usual treatment	CO2e in mass	/	/	/	/	Together (cost/CO2e per appoeintment)	Retrospective (surveys) on three-year CO2e and cost estimated with conversion factor
2014	McCarthy, C. J. et al. [20]	Power consumption of devices in the radiology department	CO2e in mass	/	/	Consumption in kWh	/	Separately	Measured over a week, estimated over a year
2018	Miltenburger, C. et al. [19]	N/A	Social cost of carbon (cost per CO2e)	/	/	/	/	Together (cost per CO2e)	Estimated
2016	Murphie, P. et al. [9]	Self-fill oxygen technology	CO2e in mass	/	/	/	/	Separately	Estimated
2020	Ortsäter, G. et al. [10]	Re-usable Inhaler	Social cost of carbon (cost per CO2e)	/	/	/	/	Together (cost per CO2e)	BIM and lifecycle product carbon footprint
2019	Ortsäter, G. et al. [11]	Re-usable Inhaler	CO2e in mass	Unit of inhaler	/	/	/	Together (cost per CO2e)	BIM and lifecycle product carbon footprint
2018	Regan, W. et al. [18]	Waste of biochemistry samples requested on a paediatric cardiology	CO2 in mass	/	/	/	/	Separately	Measured over 15 months CO2 was estimated using UK converter
2020	Starup-Hansen, J. et al. [12]	How does metered-dose inhalers (MDIs) compare to dry powder inhalers (DPIs)	CO2 and CO2e in mass	/	/	/	/	Separately	Review (Measured, LCA)
2013	Terlinden, A. et al. [21]	Cocooning vaccination	CO2e per dose of vaccine	/	/	/	/	N/A	Cradle to gate
2019	Vidal-Alaball, J. et al. [8]	Telemedicine Program	GHG in mass	/	/	/	/	Separately	Retrospective using administrative data Calculated
2016	Maughan, D. et al. [26]	Prescribing waste of flupentixol decanoate long-acting injections	CO2e in mass	/	/	/	/	Separately	Estimated using data from Oxfrod health NHS Surveys for travel data Conversion factor for CO2
2019	Wilkinson, A J. K. et al. [13]	How does metered-dose inhalers (MDIs) compare to dry powder inhalers (DPIs)	CO2e per inhaler	/	/	/	/	Separately	Estimated

Different way to compare costs and environmental impact

In the economic evaluation, the costs are part of the objective of the studies. It is then important to discover how they were taken into account compared to the environmental-related dimension.

In all of the studies, the costs were calculated separately from the environment in 56% of the case. They were calculated with the environment in 36% of the articles. Two articles ([2]; [21]) did not apply as the information were not available. (**Figure 4**)

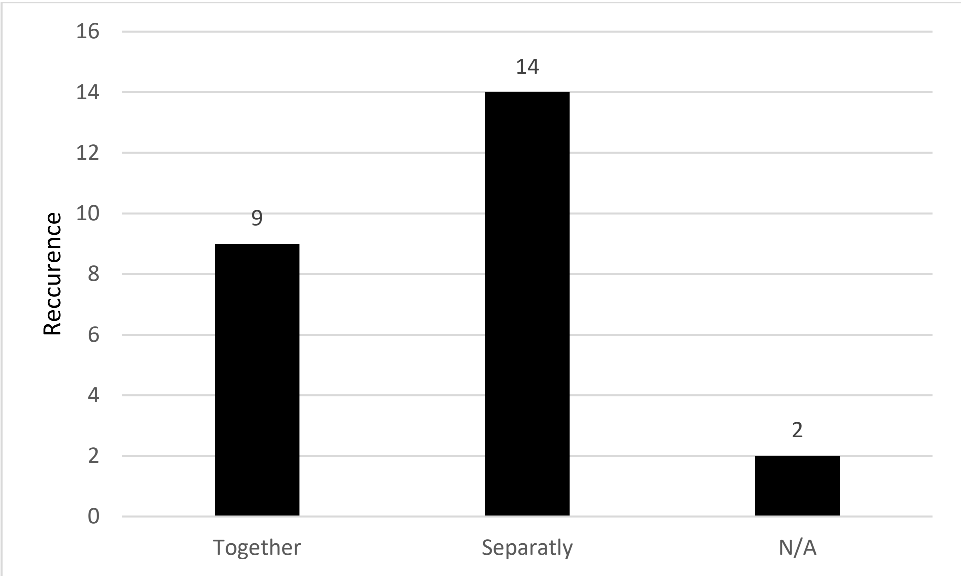

Figure 4. ***How costs were calculated with the environment?***

The studies that calculated the costs with the environment-related dimension have done it in the way that the data were presented were different as they compared the health product/process costs and impact on the environment together. The societal cost (cost per CO2) was calculated in four studies ([15], [10], [11], [19]) and was the representation of the direct impact of the health product/process on the environment and making possible to compared them. Three studies ([5], [6], [7]) calculated and compared the cost and environmental impact per appointment in the process of reducing travel distance to clinical center. Finally, two studies ([23], [24]) calculated and compared the energy efficiency of goods in the healthcare system.

The studies that calculated the cost separately from the environmental-related dimensions were the one that presented the results in the way that they were not meant to be associated. These studies compared the cost and the impact on the environment as two different items.

4. DISCUSSION

Summary of evidence

A literature review of twenty-five publications on the way that the environmental impact of health product was considered in economics evaluation thought the countries of the Europe of 12 was conducted.

As the number of publications continue to grow since 2000, the assumption that the inclusion of the environment impact of the health product increase can be made. It seems that researchers and health organizations consider to included it more systematically.

Based on the results of this study, the impact of the health product was compared differently through the literature. Most sources of evidence transform their results in CO_2 (or CO_2e). Therefore, the carbon dioxide is the most represented environment-related dimensions in the studies. It is largely because it as the most significant impact on the climate change and is well known to the public. The CO_2 equivalent is largely used across the sources as it regroups multiple gases and dimensions (energy, waste and water) into one by converting result. This makes easier to compare the health technologies impact on the environment as it limits the number of criteria with a uniform one. Some studies made the choice to implement the cost directly with this CO_2e to create the societal cost of the health product. This societal cost is the more elaborate incorporation of the environmental impact of the health technology in an economic evaluation. The societal cost needs to be more use through the economic evaluation as it usually promotes low-cost products over the consideration of the benefits to the society such as less waste and less CO_2e. Some study ([14]; [20]) made possible to calculate the societal cost, as they transformed their results in CO_2e, but they do not go any further.

The other dimension (energy, waste and water) could be more used through the literature. The CO_2 is wildly accepted for the public the indicator of reference while we talk about the environment, but direct pollution of water and soil generated by waste are as much important. Consumption and production of electricity and tap water are also very important depending of the production methods and should be fully taken into account.

There was recurrent theme of health technologies in the results. The implementation of a closer to patient clinical structure or even an out of clinic process (like telemedicine) is the most represented one. It is probably link to the fact that reducing travel needs directly reduced the carbon dioxide emission. This problematic is also link to the desire to reduce the impact of the emission of cars. Surprisingly, the problematic of the inhaler was also present through the articles. There was the waste of them (implementation of a reusable unit) and the desire to change the propellent gases used.

There is different way to calculate the costs and the environment-related dimension. The studies that calculated the costs with the environment-related dimension are the most interesting. These studies take the full spectrum of the impact of the health product and have a better way to compared them. Future economics evaluation should use this method to fully compare the heath product.

Through the results of these studies, there was no uniform way to incorporate the environmental factors to the economic evaluation. Every source worked differently, making difficult to compare their methods. Marsh et al [2] concluded the same observation in their study.

Conclusions

The interdependent relationships the public health and the environment are significant. It is then important for the economics evaluation to consider the effect of the environment on health and conversely. The finding of this review provides an overview of the situation in the "Europe of 12" at this point. As climate change become more than ever urgent, there is a growing need to include the environmental impact of the health service by the health organization and researchers.

As no uniform methods were found, guidelines should be created to encourage and standardize the economic evaluation the inclusion of the environment impact.

This literature review is not without its limitations. It is possible that the search did not identify relevant publications as some may not be available in the databases used. A comparison, which was not the point in this work, with the paper of CD focusing on the countries of the "G20" could bring more weight to this work. As the main purpose of this paper was exploratory, further work is mandatory to collect data and working methods to express the evidence needed.

5. Bibliography

[1] C. Naylor et J. Appleby, «Environmentally sustainable health and social care: Scoping review and implications for the English NHS,» *Journal of Health Services Research & Policy,* vol. 18, n° %12, pp. 114-121, 2013.

[2] K. Marsh, M. L. Ganz, J. Hsu, Str, M. berg-Larsen, R. P. Gonzalez et N. Lund, «Expanding Health Technology Assessments to Include Effects on the Environment,» *Value Health,* 2015.

[3] M. J. Connor, S. Miah, M. A. Edison, J. Brittain, M. K. Smith, M. Hanna, T. El-Husseiny et R. Dasgupta, «Clinical, fiscal and environmental benefits of a specialist led virtual ureteric colic clinic: a report of a prospective study,» *BJU International,* 2019.

[4] M. Davie, P. Jeffreson, T. Jones, T. Roberts, F. Adekunle et P. Mitchell, «Peripatetic intravenous service for metabolic bone disease: Case study in patient centred-care for new NHS,» *Current Medical Research & Opinion,* 2010.

[5] D. Lewis, G. Tranter et A. T. Axford, «Use of videoconferencing in Wales to reduce carbon dioxide emissions, travel costs and time,» *Journal of Telemedicine and Telecar,* 2009.

[6] D. Maughan, R. Lillywhite, S. Pearce, T. Pillinger et S. Weich, «Evaluating sustainability: a retrospective cohort analysis of the Oxfordshire therapeutic community,» *BMC Psychiatry,* 2016.

[7] D. L. Maughan, A. Patel, T. Parveen, I. Braithwaite, J. Cook, R. Lillywhite et M. Cooke, «Primary-care-based social prescribing for mental health: An analysis of financial and environmental sustainability,» *Primary Health Care Research & Development,* 2016.

[8] J. Vidal-Alaball, J. Franch-Parella, F. L. Seguí, F. G. Cuyàs et J. M. Peña, «Impact of a Telemedicine Program on the Reduction in the Emission of Atmospheric Pollutants and Journeys by Road,» *International Journal of Environmental Research and Public Health,* 2019.

[9] P. Murphie, N. Hex, J. Setters et S. Little, «Self-fill oxygen technology: Benefits for patients, healthcare providers and the environment,» *Breathe*, 2016.

[10] G. Ortsäter, F. Borgström, M. Baldwin et C. Miltenburger, «Incorporating the Environmental Impact into a Budget Impact Analysis: The Example of Adopting RESPIMAT® Re-usable Inhaler,» *Applied Health Economics and Health Policy* , 2020.

[11] G. Ortsäter, F. Borgström, S. Soulard et C. Miltenburger, «A Budget Impact Model to Estimate the Environmental Impact of Adopting RESPIMAT® Re-usable in the Nordics and Benelux,» *Advances in Therapy* , 2019.

[12] J. Starup-Hansen, H. Dunne, J. Sadler, A. Jones et M. Okorie, «Climate change in healthcare: Exploring the potential role of inhaler prescribing,» *Pharmacology Research and Perspectives,* 2020.

[13] A. J. K. Wilkinson, R. Braggins, I. Steinbach et J. Smith, «Costs of switching to low global warming potential inhalers. An economic and carbon footprint analysis of NHS prescription data in England,» *BMJ Open,* 2019.

[14] A. Connor, S. Milne, A. Owen, G. Boyle, F. Mortimer et P. Stevens, «Toward greener dialysis: A case study to illustrate and encourage the salvage of reject water,» *Journal of Renal Care,* 2010.

[15] L. de Preux et D. Rizmie, «Beyond financial efficiency to support environmental sustainability in economic evaluations,» *Future Healthcare Journal,* 2018.

[16] M. Back , A. Al-Attar, R. Sutton et C. Shelton, «Comparison of economic and environmental impacts between disposable and reusable instruments used for laparoscopic cholecystectomy,» *British Journal of Anaesthesia,* 2021.

[17] P. A. C. Gatenby, «Modelling the carbon footprint of reflux control,» *International Journal of Surgery,* 2011.

[18] W. Regan, D. Hothi et K. Jones, «Sustainable approach to reducing unnecessary combined biochemistry tests on a paediatric cardiology ward,» *BMJ Open Qual,* 2018.

[19] C. Miltenburger, F. Borgstrom et O. Eklund, «Ecological Benefits of Health Technologies – How to Consider Public Value in Funding Decisions?,» *VALUE IN HEALTH* , 2018.

[20] C. J. McCarthy, J. F. Gerstenmaier, A. O' Neill, S. H. McEvoy, C. Hegarty et E. J. Heffernan, «‘‘EcoRadiology’’—Pulling the Plug on Wasted Energy in the Radiology Department,» *Acad Radiol,* 2014.

[21] A. Terlinden, B. Renson, C. Ponder, J. E. Poirrier et D. Curran, «Carbon cost-effectiveness of cocooning immunization against pertussis in England and wales: An ecological perspective,» *Value in Health,* 2013.

[22] S. Adler, K. D. Scherrer , F. Rückauer et D. Daschner, «Comparison of economic and environmental impacts between disposable and reusable instruments used for laparoscopic cholecystectomy,» *Surg Endosc,* 2005.

[23] C. Köhler, S. Venditti, E. Igos, K. Klepiszewski, E. Benetto et A. Cornelissen, «Elimination of pharmaceutical residues in biologically pre-treated hospital wastewater using advanced UV irradiation technology: a comparative assessment,» *Journal of Hazardous Materials,* 2012.

[24] N. P. Burke et J. Stowe, «Energy efficiency in the radiography department: An Irish perspective,» *Radiography,* 2014.

[25] F. Barbariol, C. Deana, F. Lucchese, G. Cataldi, F. Bassi, T. Bove, L. Vertugno et A. De Monte, «Evaluation of Drug Wastage in the Operating Rooms and Intensive Care Units of a Regional Health Service,» *Anesthesia & Analgesia,* 2021.

[26] D. Maughan, R. Lillywhite et M. Cooke, «Cost and carbon burden of long-acting injections: a sustainable evaluation,» *BJPsych Bulletin* , 2016.

[27] B. Pekarsky, «The Inclusion of Comparative Environmental Impact in Health Technology Assessment: Practical Barriers and Unintended Consequences.,» *Appl Health Econ Health Policy,* vol. 18, pp. 597-599, 2020.

6. Appendix

Appendix 1

Research equation:

("belgium" OR "belgium" OR "france" OR "france" OR "netherlands" OR "netherlands" OR "holland" OR "the netherlands" OR "germany" OR "germany" OR "luxembourg" OR "luxembourg" OR "luxemburg" OR "spain" OR "spain" OR "portugal" OR "portugal" OR "denmark" OR "denmark" OR "united kingdom" OR "uk" OR "united kingdom" OR "united kingdom of great britain and northern ireland" OR "italy" OR "italy" OR "ireland" OR "ireland" OR "eire" OR "irish republic" OR "greece" OR "greece" OR "greek macedonia" OR "macedonia (greece)")

AND

("health care system" OR "healthcare system" OR "healthcare sector" OR "health care sector" OR "health care" OR "comprehensive health care" OR "health system" OR "healthcare" OR "long stay care" OR "medical device" OR "bioinstrumentation" OR "biological instrumentation" OR "biomedical device" OR "biomedical device (physical object)" OR "biomedical equipment" OR "biomedical instrumentation" OR "clinical device" OR "clinical equipment" OR "devices, medical" OR "durable medical equipment" OR "instrumentation, biological" OR "instrumentation, medical" OR "medical apparatus" OR "medical apparatus, equipment and supplies" OR "medical device" OR "medical devices" OR "medical equipment" OR "medical instrument" OR "medical instrumentation" OR "medical supplies" OR "drug industry" OR "drug industry" OR "pharmaceutic chemistry industry" OR "pharmaceutic industry" OR "pharmaceutical companies" OR "pharmaceutical company" OR "pharmaceutical industry" OR "medical technology" OR "biomedical technology" OR "medical laboratory science" OR "medical technology" OR "stains and staining")

AND

("medical assessment" OR "independent medical evaluation" OR "medical assessment" OR "medical evaluation" OR "biomedical technology assessment" OR "hta" OR "health technology assessment" OR "economic evaluation" OR "cost utility analysis" OR "cost utility" OR "cost benefit analysis" OR "cost analysis" OR "cost benefit" OR "cost benefit analysis" OR "cost-benefit analysis" OR "cost effectiveness analysis" OR "cost effectiveness" OR "cost effectiveness analysis" OR "cost efficiency analysis" OR "benefit-cost analysis" OR "economic benefit evaluation" OR "benefit evaluation" OR "economic health" OR "net benefit analysis" OR "budget impact model")

AND

("one health" OR "one health-one medicine" OR "one medicine" OR "one medicine one science" OR "one medicine-one health" OR "one world-one health" OR "planetary health" OR "environmental sustainability" OR "environmental sustainability" OR "environmental health" OR "environmental health" OR "waste management" OR "waste management" OR "waste treatment" OR "recycling" OR "equipment reuse" OR "recycling" OR "resource recovery" OR "waste recycling" OR "waste utilization" OR "renewable resource" OR "renewable resources" OR "renewable*" OR "renewable energ*" OR "renewable fuel" OR "pollution" OR "environment contamination*" OR "environment pollution*" OR "environmental pollution*" OR "pollution" OR "greenhouse effect*" OR "global warming" OR "greenhouse effect*" OR "climate change*" OR "climate sensitivity" OR "climate variability" OR "climatic change*" OR "air quality" OR "pharmaceutical pollution*" OR "green product*" OR "green building*" OR "industrial plant emission*" OR "emission standard*" OR "lower carbon" OR "environmental impact assessment" OR "environmental impact assessment" OR "natural resource" OR "natural resources" OR "natural environment" OR "environmental change*" OR "environment change*" OR "ecosystem*" OR "ecological system*" OR "ecosystem*" OR "ecolog*" OR "bionomics" OR "ecological research" OR "human ecology" OR "environmental impact*" OR "environmental fate" OR "environmental poli*" OR "pollution control" OR "environmental management" OR "ecosystem management" OR "environmental management" OR "environmental protection" OR "conservation of natural resource*" OR "environmental conservation" OR "environmental protection" OR "natural resource conservation" OR "nature conservation" OR "nature preservation" OR "environmental risk*" OR "environmental risk assessment" OR "environmental risk factor*" OR "environmental cost*" OR "environmental cost" OR "energy consumption" OR "energy consumption" OR "fuel consumption")

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