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Primary healthcare's carbon footprint and sustainable strategies to mitigate its contribution: a scoping review

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Abstract

Background The escalating climate crisis poses a significant threat to global public health. The healthcare sector, designed to protect human health is a major contributor to greenhouse gas emissions, and thus, a key driver of climate degradation. This paradox endangers both planetary and human health, making the decarbonization of healthcare, including primary care, critical. However, research on primary care's contribution to emissions and strategies for mitigation remains limited.

Aim This scoping review aimed to map how primary care contributes to healthcare's environmental footprint and determine contributing factors. Additionally, it sought to identify existing and innovative strategies to reduce the carbon footprint of primary healthcare.

Methods A comprehensive strategy was developed to systematically search both published databases and grey literature. Key terms were identified and employed in the exploration of relevant databases and internet search engines.

Results An initial search yielded 246 published articles and 25 grey literature sources. 14 additional articles were included following forward and backward searching of prominent authors and key articles. After screening and full-text review, 39 articles and 12 reports/toolkits were included. The majority of sources were opinion pieces, with limited quantitative, observational, or qualitative studies.

Primary care's carbon footprint can be classified into clinical and non-clinical sources, with significant impacts from pharmaceuticals and inhaler propellant gases. Contributing factors include limited knowledge of emission sources, lack of awareness of sustainable practices, low prioritization of sustainability, barriers including ethical concerns and over-medicalization.

Identified strategies to reduce emissions include decarbonization of patient care, increasing education and awareness, implementing non-clinical decarbonization efforts, and conducting more research to support sustainable initiatives. Developing metrics to track progress and securing policy supports to improve adoption and implementation were also highlighted as critical.

Conclusion The identification of sources of carbon hotspots in primary care is an essential precursor to enable the development of targeted decarbonization strategies. Decarbonizing primary care requires a multifaceted approach that addresses the underlying factors driving unsustainable practices. This would allow healthcare

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professionals to effectively balance the provision of high-quality patient care, while reducing their environmental impact, ultimately improving both human and planetary health.

Keywords Carbon Footprint, Environment, Greener Healthcare, Mitigation, Primary care, Sustainability

Introduction

The escalating climate crisis is recognized as the single greatest threat to global public health. This is attributable to unsustainable anthropogenic activities, primarily involving the emission of greenhouse gases (GHGs) [1–4]. Today, the consequences of inaction have propelled the previously distant concern of climate change into a pressing public health emergency [5]. A historic high in average global surface temperatures was reached in 2023, with clear evidence that this excessive warming is associated with detrimental impacts on human health [2, 6]. This underscores the urgency for proactive mitigation strategies to prevent the escalating health risks from exceeding the adaptive capacity of global health systems [5, 6].

The interconnected relationship between human health and planetary health presents a paradox for the delivery of healthcare While striving to safeguard human well-being, healthcare emerges as a significant contributor to global warming, responsible for between 4 and 5% of GHG emissions worldwide [7]. This incongruity presents a significant challenge for policymakers and healthcare professionals alike. Ensuring access to quality healthcare services remains of paramount importance for maintaining and improving population health as enshrined in the United Nations Sustainable Development Goals [8]. However, mitigating the environmental impact of healthcare provision is crucial to protecting planetary and human health, as well as ensuring the long-term sustainability of healthcare systems [9]. Addressing this apparent conflict necessitates a multi-faceted approach that balances environmental sustainability, the delivery of effective healthcare services and the promotion of positive healthy behaviors [9, 10]. By acknowledging and actively addressing this conundrum, the healthcare sector can strive to fulfil its mission of safeguarding human health while simultaneously contributing to a healthier planet for future generations. Each nation's health sector directly or indirectly releases GHGs while delivering care with ~70% of emissions derived from the supply chain for goods and services [11]. Carbon hotspots within healthcare include the running of hospitals, surgical procedures, waste management and pharmaceuticals [12–14]. Secondary care has been identified as the most resource intensive model of healthcare delivery [15]. In that setting, initiatives to date have predominantly focused on greening carbon intensive activities such as surgical theatres, intensive care and gastrointestinal endoscopy [12, 16–18]. Primary care is capable of managing up to 90% of health needs within a healthcare system but is less carbon intensive [19]. A community-based model of healthcare is ideally situated to prioritize health promotion and disease prevention alongside the management treatment models of acute illness and chronic conditions [19, 20]. Research in the UK investigating the carbon footprint of primary healthcare delivery has estimated it to account for 5770Mt CO_2eq or 20–25% of the entire NHS carbon footprint [13, 21].

As healthcare systems prioritize a transition from secondary care to less carbon intensive community care model, the development and implementation of evidence-based policies to ensure environmental sustainability in primary care must be prioritized. There are few studies examining potential carbon mitigation strategies within this sector signifying the need for research to identify decarbonization opportunities [22]. Robust research is needed to provide a comprehensive understanding of the environmental impact of primary care and to inform sustainable practice development in the sector [23]. This scoping review aims to review the existing literature on the carbon footprint of primary care, and to provide insights into existing and emerging mitigation strategies, addressing the key questions of how, where, and why does primary healthcare contribute to the carbon footprint of healthcare, and what sustainable strategies exist to mitigate these effects. The review findings will provide the basis for further research on the implementation of evidence-based sustainability initiatives within primary care.

Methods

The scoping review was conducted in accordance with the framework proposed by the Joanna Briggs Institute (JBI) methodology for scoping reviews and refined by Peter's et al. [24–26]. It was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis extension for Scoping Reviews (PRISMA-ScR) checklist (Supplementary Material 1) [24, 27]. The protocol was registered with the Open Science Framework [28].

Inclusion criteria

The review encompassed studies and reports that primarily addressed two areas: (1) assessments of the

carbon impact or analyses of the carbon footprint associated with primary healthcare services, and (2) the exploration of sustainable strategies for mitigating the carbon footprint within the context of primary care. Studies solely focused on tertiary care or hospital settings were excluded. Outpatient services delivered within the community setting were considered for inclusion if they represented a deliberate transfer of services from hospital to community settings. Studies published prior to 2010 were excluded. Eligible studies were required to be available in English and accessible in full text.

Types of information sources

All published existing evidence including primary research studies, scoping reviews, systematic reviews, quantitative and qualitative studies together with relevant editorials or other such articles from the peer-reviewed literature were sought. Additionally, grey literature, including government or organizational reports that met the established inclusion criteria were considered. Opinion pieces, perspectives and letters were considered when they offered compelling perspectives or novel insights that addressed the research question and explored potential avenues for change. The latter sources were analyzed through the lens of identifying potential for change and novel perspectives.

Search strategy

A comprehensive search strategy was developed in collaboration with an experienced information specialist to identify published studies and reports and further refined through investigator discussion. MEDLINE, Scopus, Embase, CINAHL, Global Health, and Health Business Elite databases were included. The search strategy, including all identified keywords and index terms, was adapted for each individual database. The final search strategy for MEDLINE can be found in Supplementary Material 2. Forward and backward citation tracing of key articles and prominent authors was conducted to identify any additional relevant articles not previously identified in the search strategy.

The grey literature search plan was developed in accordance with Godin et al.'s [29] application of systematic search methods to grey literature [29]. This plan incorporated four discrete searching strategies: (1) grey literature databases, (2) customized Google search engines, (3) targeted websites, and (4) consulting with relevant experts and prominent active organizations within the field of research. These complementary strategies were employed to minimize the risk of omitting relevant sources and to establish current international and national governmental and organizational policy context, motivation, and appetite for change among those working in the area with the aim of establishing the carbon footprint in primary care and resultant mitigation strategies.

Selection of sources of evidence

All citations retrieved were collated and uploaded into EndNote® (version 21.2) bibliography software and duplicates were removed. Titles and abstracts were screened by the lead investigator against the inclusion criteria. Due to the frequent absence of abstracts in grey literature documents, screening was conducted using available materials such as item executive summaries, or tables of contents. Full text articles were retrieved for all remaining articles and reports and further assessed independently for relevance by two members of the research team. Any dissension regarding study eligibility was resolved through discussion, and consensus reached. Reasons for excluding studies at the full-text stage that did not meet the inclusion criteria were recorded and reported in the final scoping review. The PRISMA-ScR flow diagram was used to present the search results and the study selection process [30].

Data extraction

A standardized data extraction chart was developed to capture relevant information including author, year, country, clinical setting, study design, research aim and key findings. Three investigators independently charted the extracted data, identifying emergent themes relevant to the research topic of carbon assessment and mitigation strategies within primary care. Validation of extracted data involved comparing results and resolving differences through consensus.

Data items

Data were extracted that contained formal results related to the source, location, and contributing factors of the carbon footprint of primary care. Additionally, data regarding mitigation strategies encompassing current and potential strategies, along with commentary addressing barriers, facilitators, and implementation strategies was extracted.

Synthesis of results

Following individual data extraction, the investigators convened and collaboratively refined the themes identified through an iterative process and grouped them in accordance with answering the three key topics of the research question: (1) how and where primary care contributes to its carbon footprint, (2) why these activities within primary healthcare contribute to its carbon footprint, and (3) identifying mitigation strategies that can be implemented to reduce to primary care's carbon

footprint. The data was collated using tables and descriptive text and analyzed to comprehensively assess both the nature of primary care's environmental impact and potential solutions for mitigating it.

Critical appraisal of sources of evidence

Peter's et al. states that critical appraisal is typically not required to be undertaken in a scoping review because the objective of a scoping review is to map the existing evidence rather than deliver a synthesized and clinically significant response to a specific question [24]. Therefore, formal critical appraisal was not undertaken.

Results

Selection of sources of evidence

An initial search of relevant electronic databases yielded 246 articles. Following the removal of duplicate entries ($n=40$), the remaining 206 articles underwent title and abstract screening. A complementary search of grey literature sources identified 12 reports, 10 toolkits, two guidelines and one framework. During the screening process, a total of 159 articles did not meet the predefined inclusion criteria, primarily due to their sole applicability to hospital care settings. Two articles were excluded because the full text was unavailable, and two toolkits were excluded due to restricted online accessibility. Fourteen additional articles were identified for full-text review based on backward and forward citation analysis of key studies and prominent authors. Following a full-text review of the remaining 59 articles by three independent reviewers, 39 were considered to meet the inclusion criteria, and of the reports, toolkits, guidelines and the one framework, 12 were deemed eligible for data extraction (Fig. 1). Details of the reasons for exclusion of studies following the full-text review are provided in Supplementary Material 3. The most frequent reasons for exclusion pertained to the limited applicability of studies to the primary care setting, with studies focusing primarily on outpatient clinics or specialist secondary care interventions.

Characteristics of sources of evidence

The 39 publications encompassed a range of quantitative studies [21, 31–36], qualitative studies [37–42], observational studies [43–46], opinion pieces [47–64] and review articles [65–68]. The majority were published from 2021 onwards while six were published prior to that year [32, 37, 40, 43, 53, 57]. Six toolkits [69–74], four reports [11, 13, 75, 76], one guidance document [77] and one framework [78] were identified from the grey literature.

Carbon footprint of primary care

The primary care activities responsible for the sector's emissions were identified in multiple studies [21, 31–34, 36, 67]. These factors are broadly classified into non-clinical and clinical activities relating to the provision of care across general medical practice, dentistry and other primary care settings (Table 1). Non-clinical activities include purchased electricity or on-site fossil fuel use, patient and staff travel, supply chain, administrative equipment and consumables, the generation and management of waste and water use [21, 31–34, 36, 67]. Clinical care provision activities involving direct patient care included diagnostic and laboratory tests, the procurement and use of medical consumables, and procedures undertaken in primary care facilities [32, 33]. In one study, an average GP consultation was estimated to account for 4.4kgCO_2eq increasing to 66kgCO_2eq when pharmaceuticals were included [21, 33]. The average carbon footprint for a dental examination in primary care is estimated to produce 5.5kgCO_2eq, which increases incrementally for more complex procedures [32]. Medicines use, including propellant inhalers and anesthetic gases, is associated with a significant carbon footprint in primary care [21, 31, 32, 34, 36]. The average carbon footprint for a prescription medication item is estimated to be 5kgCO_2eq [34], which increases to 28kgCO_2eq for a large volume short-acting beta-agonist (SABA) pressurized metered dose inhaler (pMDI) compared to around 1kgCO_2eq for a dry powder inhaler (DPI) [34].

Factors preventing/impeding uptake of decarbonization strategies

A number of key factors indirectly responsible for the on-going generation of primary care's carbon footprint, and therefore, adoption of sustainability practices, were identified in the review. These included lack of knowledge regarding both sources of GHG emissions [37, 39, 40, 42, 46, 47, 51–53, 63, 66] and sustainable healthcare initiatives [41, 44, 45, 66], perceived barriers to adoption of sustainable healthcare practices [37, 38, 40, 42, 44, 47, 62, 66–68] and what has been broadly described as 'overmedicalization' [31, 36, 47, 48, 55, 57, 58, 60, 64].

Lack of knowledge of sources of GHG emissions in primary care

The review findings identified limited knowledge among primary care practitioners on sources of GHG emissions in general, and more specifically, primary care's contribution to climate change, largely due to a lack of education [37, 39, 42, 66]. An understanding of the connection between GHG emissions and their impact on climate change is also limited [40, 46, 47]. Practitioners felt they were uninformed or unfamiliar with the connection between resource use and environmental impact, and this made it challenging to prioritize sustainability in daily clinical decisions [40]. This was felt to be in part

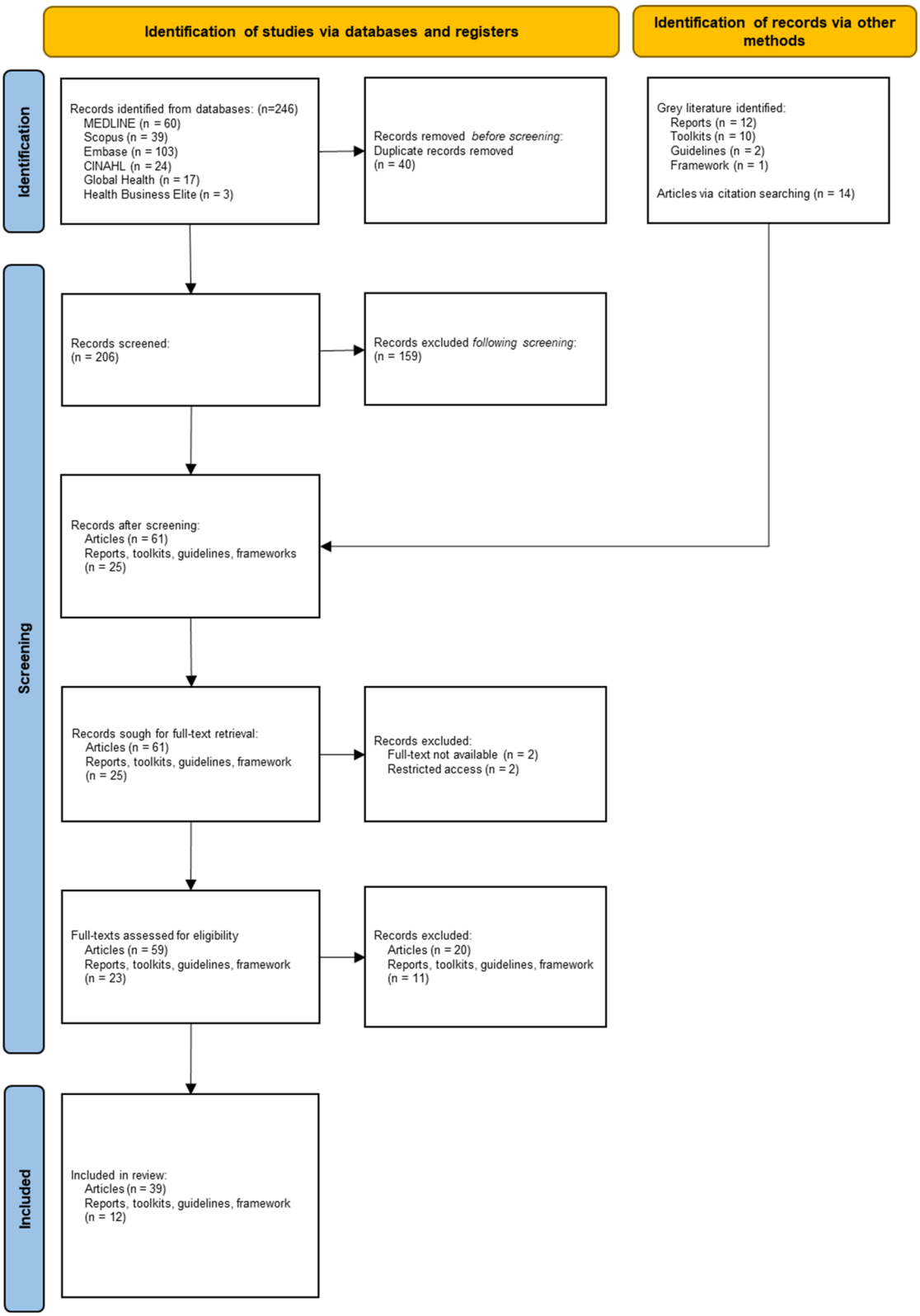

Fig. 1 PRISMA Flow chart adapted from Page et al. [30]

Table 1 Sources of the clinical and non-clinical carbon footprint of primary care

Type	Activity	Description
Clinical	Medical instruments & equipment	*Stethoscope, thermometer, scales, examination bed, x-ray, autoclave, dental instruments*
	Medical consumables	*Bandages, gloves, masks, swab tests, needles, syringes, dental materials*
	Pharmaceuticals	*Medicines and their supply chain carbon footprint contribution*
	Metered dose inhalers	*Propellant gases in pressurized metered dose inhalers*
	Anesthetic gases	*Nitrous oxide inhaled gases used in dental procedures*
Non-Clinical	Building energy	*Gas & electricity use and on-site fossil fuel consumption – heating, cooling,* etc.
	Water and waste	*General (non-recyclable waste), paper, plastic waste collection, disposal and recycling (if applicable) Water treatment and supply services*
	Business services	*Couriers, deliveries, logistical support, business administration services*
	Non-medical equipment	*Computers, desks, tables, chairs, printers*
	Non-medical consumables	*Paper, ink, toners, batteries, stationary*
	Travel	*Patient travel and staff commute to work*

compounded by the lack of robust data on the environmental or carbon footprint of various medications and therapies making it difficult to integrate any consideration of these into treatment selection [42, 51]. Qualitative studies and opinion pieces consistently referred to the need for more data on climate intensive areas in primary healthcare to help inform decision-making [39, 42, 51, 63]. While the development and integration of sustainable healthcare into the curricula of undergraduate health professional education is proceeding [52, 53, 66], education aimed at enhancing knowledge and awareness at the postgraduate or practitioner level remains largely elective [46, 53].

Lack of awareness of sustainable healthcare initiatives

A lack of awareness around sustainable healthcare initiatives among primary care practitioners is also acknowledged [41, 66]. It was opined that when aware of the importance of the climate emergency, practitioners were often faced with a disconnect between a willingness to commit to sustainable practice and the relative lack of tools available to support them in achieving this [41, 44]. There was also an apparent lack of appreciation of the health co-benefits that could be achieved should sustainable healthcare strategies be practiced [45]. It was felt that the non-medical workload, particularly administrative work, combined with the burden of managing multimorbid patients, may limit the potential sustainable healthcare initiatives primary healthcare professionals can adopt [41].

Barriers to adoption of sustainable healthcare practices

Practicing sustainably is not regarded as a routine daily task in primary care practice [37]. Practitioners frequently expressed ethical concerns regarding the potential for sub-optimal patient care should alternate, more sustainable practices be adopted [37, 40]. Climate change and sustainability was for some not considered a priority, that it was more perceived as a global issue and not a 'local issue' *per se* [37, 67]. This also extended to a perceived potential for infection control protocols to be compromised when implementing sustainability guidelines [40, 42, 44]. Other barriers to the adoption of sustainable practices identified included financial constraints and consequent implications and resistance to change amongst practitioners [42]. Limited time to learn about and implement sustainable practices in existing under-resourced settings was ultimately regarded as challenging [67]. There was a strong perception of a lack of leadership from individuals in positions of influence within healthcare to implement, maintain and strive for sustainability within primary care [42, 44]. This was then mirrored by a corresponding lack of leadership and green incentives in individual primary care practices [38]. The absence of robust measurement tools to track progress in the adoption and implementation of sustainable practices together with a lack of evidence-based guidance are perceived to be further barriers [38, 47, 62, 66, 67]. This was reflected in Wicklum et al.'s research which found that the lack of an evidence base for the use of green toolkits to support more sustainable clinical decision-making, deterred their adoption in the practice setting [68].

Over-medicalization

The theme of over-medicalization, characterized by the excessive use of medical interventions, including diagnostic testing, treatments and pharmaceuticals, which often do not provide any significant perceived benefit to the patient, was identified in the review as a factor contributing to primary care's carbon footprint [48]. In addition to the environmental costs of over-medicalization, there is the apparent additional financial costs associated

with various excessive healthcare interventions without any discernible justification or therapeutic benefit for the patient. Overuse of laboratory diagnostic tests and referrals for investigative procedures not adhering to clinical guidelines is common, with considerable emissions resulting from single use instruments, transport and facility costs [48, 64]. Reasons for the emergence of over-medicalization include the increasing treatment of all health problems solely using a biomedical approach, and in part by a transition from a predominantly infectious disease presentation to the dominance of chronic disease resulting in increased medicines use [54]. Over-medicalization is further compounded by changes in models of care with a high degree of specialization of hospital-orientated healthcare delivery, hindering the holistic patient-centered approach available in primary care [54]. This may contribute to a lack of rational prescribing in general, which does not fully consider multiple factors including environmental cost, when providing clinical care decisions [47]. Over-prescribing of medicines, in addition to diagnostic and laboratory testing overuse, is common [48]. Pharmaceuticals are a carbon hotspot for waste within primary care and this waste is consequently classified as 'low-value' care [48, 57, 58, 60, 64]. Over-prescribing, polypharmacy and other 'low value' interventions with potentially minimal derived benefits, can result in significant negative patient impacts, including the development of disproportionate adverse reactions, and associated environmental and financial risks [55]. Inhaler prescribing constitutes a significant carbon hotspot, and many pMDI reliever inhalers are inappropriately prescribed to individuals with uncontrolled asthma, offering little to no value to patient care [31, 36]. SABA overuse, can lead to an 8.1-fold increase in *per capita* carbon footprint [36].

Mitigation strategies

Patient care decarbonization strategies

The adoption of low carbon strategies to reduce the use and carbon intensity of pharmaceuticals and laboratory and diagnostic tests was felt to offer a significant opportunity to address the prominent carbon footprint within primary care [13, 75]. Strategies for medicines optimization were prominent [43, 48, 49]. This included identifying and deprescribing low-value care interventions, prescribing low-carbon alternatives such as switching from pMDIs to low carbon alternatives where clinically appropriate, the use of social, green and blue prescriptions and promoting strict adherence to evidence-based prescribing guidelines [43, 47, 58, 64, 69, 75, 77]. Another avenue for clinical decarbonization included a shift in the model of care for patients from a treatment-based model to a preventative one encompassing the broader social and economic determinants of health [54, 59, 78]. The utilization of digital technologies, such as telehealth, within a revised model of care could reduce the carbon hotspot associated with patient travel. This would offer advantages for both patients and providers by potentially increasing access to care, improving convenience and ultimately reducing unnecessary carbon emissions associated with travel [35]. Increasing patient involvement in clinical decision-making would also provide opportunities for waste reduction [48].

Education and awareness

Healthcare professionals identified a lack of awareness around the effect of climate change and the need for education on interventions and supports to practice more sustainably [37, 38, 40–42, 45, 66]. Improvements in environmental literacy is felt to be fundamental in providing clinicians with the ability to identify carbon intensive activities and interventions [39, 47, 52, 53, 56, 61]. This would support primary healthcare providers to reduce unnecessary waste and reduce the carbon intensity of services and interventions without compromising patient care and safety which is of particular significance given that no such measures could be enacted were they to undermine the care and welfare of the patient. Embedding sustainability into the education of healthcare professionals at undergraduate and postgraduate level was identified as a necessary requirement to integrate fundamental sustainability practices into clinical decision-making [46, 52, 61, 66, 76]. Inclusion and education of patients in a shared decision-making model with healthcare providers was also identified as an important strategy to consciously reduce unnecessary diagnostic testing and medicines prescribing and to increase patient adherence to therapies, resulting in a reduction in the carbon footprint of primary care [44, 48]. Educational initiatives and interventions, such as toolkits, guidance documents, and frameworks, have been crafted to inform and support healthcare professionals in optimizing their clinical operations and patient care [69–71, 74, 77, 79]. These resources, once implemented can serve as a starting point to identify and develop interventions to drive quality improvement changes aimed at maximizing sustainable value [55, 78]. Implementation of the available resources and integration of sustainability and quality improvement in primary care practice is not feasible until practitioners are fully educated with the ultimate aim of promoting environmentally sustainable clinical behavior change [66, 68, 78].

Decarbonization of infrastructure

Reports and toolkits identified in the grey literature search highlighted the need for decarbonization of

primary care infrastructure and non-clinical activities. These included upgrading primary care practices' energy usage, effective resource utilization, and efficient waste management strategies [13, 72–75]. Reducing energy usage through building insulation, sophisticated energy control systems, energy efficient appliances and switching from on-site fossil fuel combustion to lower carbon energy sources has the potential to reduce energy use of facilities by up to 40% [13, 21]. Avoiding unnecessary waste generation and prioritizing waste management, including segregated recycling of non-medical consumables, and safe disposal of medical consumables, combined with conservation of energy and water are fundamental strategies to decarbonize primary care [66, 71, 73, 74].

Need for research and audit

There is recognition that healthcare, including primary care, urgently needs a more robust research agenda focused on environmental sustainability, to facilitate the adoption of green practices and to reduce carbon emissions through identifying new approaches to delivering healthcare [13, 63]. Research and development in novel green technologies has been proposed as a solution to achieving sustainability targets [13, 57]. Research should also prioritize evidence-based interventions to maximize the effectiveness of decarbonization efforts [50, 55, 66]. This would include establishing clear baselines through practice audits, allowing measurable targets to be set with defined outcomes [66, 72, 73, 75]. Furthermore, research into implementation barriers to adoption of sustainable strategies and the effectiveness of different strategies is key [38, 68]. By prioritizing research and audit, primary care can develop a data-driven approach to reducing its environmental impact and track progress towards a more sustainable future while continuing to deliver safe and effective care which provides optimal healthcare outcomes [51, 62, 66].

Policy and supports

Findings from practitioner interviews in qualitative studies identified the need for policy interventions to establish the implementation of clear practical guidance and the setting of targets for sustainability initiatives [38]. A call for broader policy interventions to mandate sustainability in undergraduate education, as well as requiring its accreditation in postgraduate registrations, will facilitate sustainable practice uptake. The need to mandate the integration of carbon impact analysis of medicines and interventions into formularies to assist in the decision-making process undertaken by healthcare professionals also requires policy initiatives [47, 52, 53, 66]. Supports available to clinicians are limited to toolkits, and broad guidance which are not as yet not mandated for adoption [11, 69–77].

Additional findings from qualitative studies with primary care practice managers highlighted that consensus regarding adoption of sustainability initiatives would be facilitated if the financial benefit was explicit [42]. Mitigation strategies were often identified as unfeasible by clinical decision-makers in the absence of financial incentivization which was considered an important facilitator for accelerating change [38]. Creating financially competitive advantages for environmentally sustainable strategies or pharmaceutical manufacture would reward clinicians, practices and pharmaceutical companies who strive to achieve net zero [51].

Discussion

The findings from this review identify that primary care's GHG emissions and its overall carbon footprint comes from both its clinical and non-clinical activities. The review further reveals that the principal sources of primary care's carbon footprint are linked to particular clinical hotspots [21]. Identification of carbon hotspots is an essential precursor to enable the development of targeted decarbonization strategies, and global decarbonization is critical to address global warming and the climate crisis [80]. Effective decarbonization of primary care necessitates a multifaceted approach that must address the underlying factors driving these carbon-intensive activities. The 2021 Healthcare without Harm roadmap report provided clear guidance on how healthcare can make significant reductions in emissions by implementing seven high impact actions facilitating targeted interventions to reduce GHG emissions, many of which are incorporated into the toolkits and frameworks identified in this review [81].

However, to effectively decarbonize, key underlying factors preventing the uptake and adoption of sustainable strategies, highlighted in the review, must be addressed. These include insufficient understanding and knowledge of both GHG emissions from primary care practices and sustainable healthcare initiatives together with barriers to adopting greener practices. In addition, mitigating the carbon footprint in healthcare settings presents inherent complexities for practitioners due to ethical concerns related to the perceived conflict between decarbonization initiatives and delivering optimal patient care [40, 44]. There are also underlying concerns surrounding the perceived lack of robust evidence supporting sustainable initiatives and interventions [42]. This is of particular significance as healthcare practitioners in primary care must be satisfied that any changes made to their practice to make it more sustainable must not come at the expense of patient safety and health outcomes. Nevertheless, for

primary care to practice more sustainably, there is a compelling need to address these concerns and perceptions of any compromise on patient care and well-being, for the successful adoption and implementation of effective mitigation strategies.

Education

To drive transformative change within primary care, healthcare professionals must have an in-depth understanding of the complex interplay between climate change and health outcomes, and the environmental impact of the healthcare they deliver. Interestingly, there is an acknowledged disconnect between recognizing the benefit of reducing their personal environmental footprint yet failing to acknowledge the environmental impact of their professional practice [37, 38]. Education of current and future healthcare professionals is therefore fundamental to addressing this deficit. Various curricula on planetary health being delivered in undergraduate healthcare programs provide a roadmap for the integration of these topics into health professions' education [56, 82–89]. However, it is challenging to incorporate new material in an already overcrowded curricula and McKimm et al. calls for a re-thinking of health profession's education leadership in relation to the planetary health emergency, suggesting that an 'eco-ethical leadership approach' is required, centered around sustainability, values, collaboration, justice, advocacy and, if needed, activism [90].

Similarly, among existing practitioners, adoption of sustainable practices was perceived to be impeded by a lack of knowledge and awareness of how to deliver greener and more sustainable care [41]. It is apparent that they should be provided with training and resources to embed the principles of sustainable healthcare into their daily practice, as described by Mortimer in 2010 [10]. The four core principles fundamentally address key factors driving carbon footprints in healthcare practice, namely, reducing care in general to that which is required to provide optimal safe patient care while also mitigating the environmental impact of the care delivered.

If the continued professional development of those who practice in primary care address these principles and how to adopt them into daily practice, multiple benefits can be gained for both human and planetary health. There are a plethora of resources available to support the pathway to sustainable practice for healthcare professionals, including those working in primary care identified in this review. At present, however, knowledge is often only broadened by those interested enough to elect to self-educate themselves, resulting in considerable variation in knowledge and awareness, often compounded by a lack of time and competing priorities. However, global communities of active advocates for more sustainable healthcare demonstrate how green initiatives can be implemented from concept to fruition with know-how, collegiality and a shared vision and purpose to address planetary health and climate change, predominantly on a voluntary basis [77, 91–95]. Increasingly, professional representative organizations are addressing planetary health practices paving the way for their sustainable incorporation into accreditation standards for professional practice [96–101]. In addition, post-graduate educational activities are also incorporating sustainable healthcare in their curricula [102].

The mitigation strategies identified in this review to address the carbon footprint of primary care can be adroitly categorized as follows:

Prevention

A consistent theme of the review findings was a perceived over-medicalization of healthcare and its interventions. The first principle of sustainable healthcare is 'prevention', as described by Mortimer in 2010 [10]. The most effective way to reduce the negative environmental impacts of healthcare activities is to limit the need for them. Promotion of public health and preventative medicine reduces the demands on healthcare systems, including hospital admissions and healthcare appointments [103]. Preventative healthcare, although widely regarded as the most sustainable and economical model of care with improved outcomes for patients, remains under-utilized [104, 105]. Embracing a shift from curative to preventative care, characterized by early detection and management and treatment protocols that addresses the underlying social determinants of health, is required. This would contribute to reducing primary care's environmental burden arising from pharmaceutical prescribing and the care associated with the treatment of chronic disease. Through its network of healthcare professionals in the heart of communities, primary care is well-placed to further enhance and champion this paradigm shift.

Enhanced patient self-care

To further address over-medicalization, patient self-care must be addressed. Empowering patients to take a greater role in the management of their healthcare has the potential to reduce disease and pre-empt complications [10]. Self-care centers on empowering patients to be involved in decisions about managing their care with appropriate support from healthcare providers, leading to better outcomes and crucially, more sustainable healthcare interventions [106]. It centers on behavioral change and lifestyle modification based on the seven

pillars of self-care, supporting the development of the health literate patient [107].

Patient travel

Patient and heath professional travel were identified as significant contributors to GHG emissions [33]. The benefit of healthcare professionals advocating for reduced private car dependency and increasing active travel both reduce emissions and bring various health co-benefits associated with increased physical activity [108, 109] Embracing digital health technologies, such as telehealth, has emerged as a potential green solution to patients travelling for care [65, 110]. However, this must always be balanced both with patient safety and optimal healthcare outcomes. Telehealth provision requires careful clinical triaging of suitable patients to ensure its benefits outweigh any potential drawbacks such as the importance of physical examinations requiring in-person consultations in determining appropriate therapeutic interventions, and ensuring the timely referral of acute cases to in-person consultations, if necessary [111]. Telehealth should primarily serve as a medium within the continuum of longitudinal care rather than for acute care or new patient settings [112]. This ensures that patient-centered, value-driven care remains the focus, as established provider-patient relationships are crucial for the delivery of effective remote care and for maintaining continuity, safety, and quality of care over time [112, 113]. Telehealth may also contribute to reduced emissions associated with staff travel where they can work from home, although such opportunities may be limited due to the need for a frontline presence.

Lean service delivery

Lean service delivery, focusing on improved clinical decision-making in the selection and targeting of interventions, reduces lower-value interventions and their associated environmental impacts [10]. Streamlining care can reduce waste from low-value care, and primary care practitioners have the potential to significantly reduce their carbon footprint by reducing the need for ambulatory care, hospital admissions, and outpatient visits, when patient care is optimized within the community setting. While improving the value of a healthcare intervention needs to first determine the potential health outcome for patients and populations, the environmental, social and financial impacts must also be taken into account [78].

Prescribing

Born et al. identified that the overuse of medicines including antibiotics, diagnostic tests and lack of adherence to evidence-based guidelines, pose a negative environmental impact that is disproportionate to their demonstrable patient benefit [48]. Overuse has been described as a pervasive problem, and a significant minority of clinical care is low-value, wasteful of financial resources or even harmful [114, 115]. This review identified prescribing of pharmaceuticals as a carbon hotspot in primary care. The environmental impact of the manufacture and use of medicines is significant [116, 117]. Inappropriate prescribing of drugs is associated with unnecessary healthcare costs and risk of side effects for patients [118]. Over-prescribing of antibiotics can lead to antimicrobial resistance, which is already exacerbated by climate change [119]. Reducing unnecessary prescribing can result in significant carbon savings, although progress can be slow [120]. There is also ample opportunity to explore and implement non-pharmacological interventions including social prescribing and nature-based (blue and green) prescribing, which could help in promoting pro-environmental behaviors with additional health co-benefits [121–124].

Adopting an 'eco-directed and sustainable prescribing' approach is recommended, consistent with a 'choosing wisely approach' [48, 125]. For patients on high-value medicines, ensuring that they are taken appropriately will ensure optimal patient outcomes and optimal value of care [126]. Medicines optimization strategies, including structured medicines reviews, are advocated to identify and address any therapy-related problems and to reduce potential waste [50, 99, 127]. Most work in decarbonization of therapeutic interventions has focused on anesthetic gases and propellant inhalers, and represents a strong inroad into eco-pharmacostewardship initiatives with significant carbon savings [128–130]. Even greater carbon savings can be obtained with optimizing reliever inhaler use and adherence to clinical care plan improvements [131]. Switching initiatives can be impeded by lack of knowledge and assistance, and rigorous implementation strategies are required to support practitioners and patients [132].

The detailed carbon footprint of inhalers is based on the ability to calculate the CO_2 equivalences of propellant gases. However, similar detail is lacking for most medicines which prevents making carbon-informed prescribing choices. Such choices would be aided by the availability of precise information on the environmental and carbon impact of medicines, but is currently lacking [133]. However, progress is being made towards the development of an online Medicine Carbon Footprint Classifier. This will integrate clinical, cost and carbon information by adapting the Triple-C framework and will support sustainable choices when prescribing and dispensing in primary care [134]. The Scottish Government has recently published a draft guidance for achieving

value and sustainability in prescribing [135]. Its aim is to reduce the use of low-value medicines and ensure the effective use of medicines with limited clinical value throughout NHS Scotland, but other jurisdictions may also benefit from the guidance, including primary care. Pharmaceutical packaging is associated with a significant carbon footprint, and reducing packaging, or using more sustainable packaging solutions by the pharmaceutical industry will also contribute to more sustainable healthcare.

Low carbon alternatives – non-clinical

In the clinical setting, primary care has ample opportunity to substitute carbon-intensive interventions with low-carbon alternatives, with no detriment to patients. Introducing a circular economy approach to selected clinical consumables including reusable personal protective equipment (PPE) and instruments is feasible in clinical primary care practice. From a non-clinical perspective, decarbonization of primary care workplaces and operational resource use provide opportunities for carbon savings without impacting on patient care. Conscious efforts to transition to renewable energy sources and introduce practical energy saving initiatives are feasible through the development and adoption of practice policies. Further policies could focus on water conservation and appropriate waste management. Effective waste management strategies offer opportunities to achieve both cost and carbon savings. Green toolkits that encourage sustainability in the practice setting foster conscious decision-making and energy-saving habits. Decarbonization strategies, such as insulation and retrofitting of primary care practice premises, will require substantial investment and may require financial incentives and government supports to encourage and accelerate their adoption and realize emission reduction benefits [136, 137].

Practice audits & research

Whatever decarbonization strategies are introduced into primary care, this review identified a need for practice audits and detailed metrics to establish and track performance improvements demonstrating the success of any such strategies [39, 51, 62, 71]. As the findings of this scoping review show, there is a notable lack of any assessment of the impact of sustainability measures in the peer-reviewed literature in the primary care sector. Such an assessment would optimally review the feasibility of their adoption, their contribution to reducing the carbon footprint of the provision of care and the financial impact of their implementation. While initiatives led by organizations such as the Centre for Sustainable Healthcare's Sustainable Network Hub have shown promising results; further research to support and expand their impact is required [94]. A knowledge gap exists in metrics due to the inability to accurately measure the environmental impact of many primary care activities, and thus, to determine any resultant reductions obtained following the introduction of carbon saving initiatives. The ability to precisely determine CO_2 equivalences of anesthetic gases has led to their phasing out in favor of more environmentally favorable alternatives and similar strategies have been successful with pMDIs [129, 138]. The accurate quantification of all healthcare goods including pharmaceuticals and services is needed in an easily assessable forum so that the most sustainable option can be chosen by practitioners as they make care decisions in the practice setting.

Mortimer attests that sustainability should be included as a key domain of quality in healthcare into the future [139]. Clinical audit is the component of clinical governance used to assess quality-of-care domains of an effective healthcare system, and an appropriate framework to incorporate sustainability initiatives is the Sustainability Quality Improvement (SusQI) framework [139–141]. In SusQI, the "sustainable value" of a service is determined by measuring health outcomes against the "triple bottom line" which is its environmental, social and economic costs and impacts. By considering outcomes for the whole population as well as for patients, sustainable value can be used to drive improvements to health equity. Sustainable value prioritizes patient safety through implementing mitigation strategies that address the root causes of climate change, thereby reducing patient exposure to climate-related health risks. These proactive measures offer a level of protection that can extend beyond the adaptive limits of healthcare systems alone, creating a safer environment for patients amid climate challenges. Indeed, it is recognized that measuring the impact of sustainable quality improvement initiatives must be multidimensional to capture meaningful outcomes heretofore not considered in conventional quality improvement studies [142]. Primary care practitioners should be educated on and adopt SusQI as an integral component of their quality improvement initiatives [78]. This can also be extended to the research of sustainable interventions in primary settings in due course.

Contribution of patients

The review highlighted that patients need to be part of the solution in reducing the carbon footprint of healthcare [50]. Initiating conversations about climate change and discussing environmental issues with patients should become more commonplace [50, 106]. Eco-literate patients if given the opportunity, can be empowered to make choices that are better for their health and

for the planet. They will understand a healthcare provider's commitment to sustainable or green prescribing, and the need for optimum compliance with any prescribed medications which in turn should provide improved outcomes for patients in addition to reducing the carbon footprint of their pharmaceutical therapy. Discussing non-pharmacologic interventions and/or eco-informed prescription of pharmaceuticals should be co-decided with the patient. Richie has coined the term 'Green informed consent' i.e. the sharing of climate information with patients, offering options for lower-carbon health care, and accepting the patient's right to decline treatments which are deemed to be too carbon intensive for the patient's own values [120, 143]. The potential feasibility and adoption of such an approach with patients will become apparent in time.

Policies

To drive transformative change, the implementation of strategic goals within healthcare systems through climate action policies must be established at all levels including primary care. Many countries and jurisdictions have published such policies. Within the UK, the NHS has published its policy to achieve a net zero health service by 2050 and detailed its roadmap of initiatives, interventions and guidance to healthcare professionals [13]. Financial savings and incentives can serve as powerful motivators, rewarding positive behaviors such as reducing energy consumption or using eco-friendly products. The findings of this review have highlighted that the economic impact on primary care of delivering more sustainable care requires further research. Being able to tangibly demonstrate to healthcare professionals from the findings of robust research, that sustainable initiatives can be delivered in a cost-effective manner, would undoubtedly incentivize them to more broadly adopt and implement greener practices in their delivery of primary care. Additionally, legislative mandates promoting sustainable choices, over ones that are not, are essential. By combining clear policies with dedicated leadership, legislative enforcement, and strategic incentives, primary care can significantly reduce its carbon footprint and achieve long-lasting sustainability.

At the heart of primary care is its workforce, and it must be empowered to enable it to optimize the delivery of care that prioritizes patient well-being while ethically minimizing resource-intensive and wasteful practices. Moreover, this empowerment will prepare them to advocate for environmentally responsible practices [144–146]. Leadership must come from both organizational management and government, supporting a clear vision that significantly alters care delivery, staff roles, and patient involvement, with sustainability becoming a core quality principle [139].

Strengths and limitations

This scoping review aimed to map the existing literature on primary care's contribution to the carbon footprint, establishing a baseline for future research. The use of three reviewers to finalize the selection of items to include in the review and the individual extraction of data represent strengths with the review. However, there are potential limitations. Despite a robust search strategy, the possibility of missing relevant literature remains. There is a rapid growth in publications relating to the topic in both the biomedical and grey literature, and newer publications may not have been captured in this review. This is evident from a systematic review published after the completion of this review which examines the strategies and tactics to reduce the impact of healthcare on climate change across all the care sectors [147]. The review leaned heavily on commentaries and editorials, with limited primary research specifically focused on primary care, but this is also characteristic of a rapidly evolving topic such as climate change, where the research base is in its early stages.

Conclusion

The climate crisis presents a dual threat: it not only has an adverse impact on patient health, but also undermines healthcare systems' ability to deliver care. The global healthcare sector has a significant carbon footprint and primary care's carbon footprint is a significant direct source of this. Implementing mitigation strategies will benefit both human and planetary health. The rapidly developing climate crisis requires immediate action. This includes a more sustainable model of care delivery that requires changes of both a clinical and non-clinical nature. Such changes include leaner service delivery, "greener" prescribing, and targeted research and policy change. Crucially, it also requires focused education for those both delivering and receiving that care. Only then can an effective yet low carbon intensive model of primary care be achieved.

Abbreviations

CO_2	Carbon Dioxide
DPI	Dry Powder Inhaler
Eq	Equivalents
GHG	Greenhouse Gases
GP	General Practitioner
JBI	Joanna Briggs Institute
Kg	Kilogram
Mt	Metric Ton
NHS	National Health Service
pMDI	pressurized Metered Dose Inhaler

PPE	Personal Protective Equipment
PRISMA-ScR	Preferred Reporting Items for Systematic Reviews and Meta-Analysis extension for Scoping Reviews
SABA	Short-Acting Beta-Agonists
SusQI	Sustainability Quality Improvement

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

Supplementary Material 3.

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Authors' contributions
SJW, AOL and ML conceptualized the study. SJW, AOL and ML collected and analyzed the data. SJW drafted the manuscript with assistance from AOL and ML. AOL, CB, SL, AV and ML edited and proofed the manuscript. All authors read and approved the final manuscript.

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The authors declare no competing interests.

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