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Integrating environmental sustainability into hospitals performance management systems: a scoping review

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Abstract

Introduction Among the healthcare sector, hospitals are the most resource-intensive infrastructures, contributing significantly to environmental degradation. As global sustainability imperatives intensify, there is a critical need to integrate environmental sustainability into hospital performance measurement systems. The study objective is to highlight the most recurrent environmental performance for hospital sustainability from the recent scientific literature and identify key performance indicators.

Methods This study employs a scoping review methodology to analyze peer-reviewed recent publications addressing environmental sustainability performance measurement and management in hospitals. The literature search was performed using PubMed, Web of Science and Scopus databases. The search was limited to papers published from 2009. The initial searches resulted in 545 studies. The final sample included 22 papers.

Results The review identifies 6 key sustainability domains: energy management, waste management, water consumption, greenhouse gases emissions, transportation and mobility, and site sustainability. The results underscore the multidimensional nature of environmental performance in healthcare facilities and reveal significant variability in the scope and specificity of existing metrics across studies.

Discussion The findings are synthesized to propose a unified, indicator-based environmental sustainability assessment framework for hospitals with a set of 18 environmental key performance indicators (EKPIs). The results underscore the multidimensional nature of environmental performance in healthcare facilities and reveal significant variability in the scope of existing metrics across studies. The findings highlight the necessity of integrating standardized indicators into hospital performance assessment frameworks to ensure comparability, track progress, and drive improvements. Additionally, the lack of harmonized measurement systems poses challenges for benchmarking and scaling sustainable practices across diverse healthcare settings.

Conclusion This study contributes to the ongoing debate on sustainable healthcare by proposing a structured framework of EKPIs based on the most recent scientific literature and tailored to hospital environments. The framework offers hospital administrators and policymakers actionable tools to monitor and enhance environmental performance.

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Introduction

The healthcare sector is one of the most significant contributors to environmental damage, accounting for 5.2% of global greenhouse gas (GHG) emissions [1]. Key sources include energy-intensive operations, such as heating, cooling, lighting, and medical equipment, as well as the production and disposal of pharmaceuticals, medical devices, and single-use supplies [2]. Within healthcare delivery units in OECD countries, hospitals are the primary contributors to climate change emissions, accounting for 28.6% of the total, compared to ambulatory care services, which contribute 18%. In hospital-based healthcare models, such as those in the US, the proportion of GHG emissions attributable to hospitals is even higher, reaching up to 36% [3]. While large public and private entities in other sectors may consider short-term trade-offs between profitability or return on investment and environmental sustainability within the context of long-term planning and operational management, healthcare systems cannot compromise clinical outcomes for environmental sustainability. Instead, the focus should be on the identification of mutually beneficial solutions with initiatives that enhance environmental sustainability without compromising the efficacy and effectiveness of healthcare system operations. The increasing attention to environmental impacts within healthcare institutions highlights a growing recognition of their importance [4]. However, to enable meaningful progress, a structured framework for performance measurement must be established, addressing the multifaceted dimensions of environmental impact and guiding process improvements and strategy development.

The study adopts a scoping literature review approach to identify key environmental sustainability dimensions and performance indicators to develop a set of indicators for measuring environmental performance (EP) across these dimensions. These indicators can be integrated into existing performance evaluation frameworks of healthcare organizations, such as Balanced Scorecards, thereby incorporating an increasingly relevant informative component for progress towards sustainability practices in healthcare. This area of hospital evaluation represents an intersection between healthcare organization or hospital administration, and the management of the built environment, including hospital design. It reflects a multidisciplinary approach that combines operational efficiency, strategic planning, and sustainability within healthcare organizations.

While other literature reviews have explored the field of environmental sustainability impacts in hospital facilities [5–7], this review introduces a novel element by adopting a performance-based approach, identifying a set of environmental key performance indicators to evaluate the various dimensions of sustainability in hospital environments. In particular, McGain & Naylor reviews have introduced the concept of environmental impact measurability in healthcare organizations, the study does not select indicators to measure environmental performances. At the same time, A. P. Blass et al. [5] and Galvão et al. reviews does not provide a list of key performance indicators to be compared when evaluating an healthcare organization.

The approach adopted ensures not only the measurability of sustainability efforts but also facilitates comparability over time, thereby offering a more systematic and actionable framework for assessing and improving sustainability performance in healthcare environments.

Performance measurement and management in healthcare organizations has a long tradition and found a fertile ground for its expansion and evolution [8–10] since the inception of New Public Management (NPM) and its practices during late 80's and the 90's of the last century [11–13]. NPM prioritizes efficiency, cost-effectiveness, and accountability, encouraging healthcare organizations to adopt measurable performance standards. This shift has led to the implementation of performance metrics and performance evaluation systems, helping to assess healthcare delivery against predefined targets and supporting continuous performance improvements. Over time, the traditional control measurement systems, based on accounting- metrics, have been complemented by multidimensional performance measurement such as the Balanced Scorecard, in order to capture both financial and non-financial results [14, 15].

One central role in performance management is played by performance measurement which focuses on tracking and evaluating specific metrics and outcomes within the broader process of using those measurements, to set goals, make decisions, and improve overall organizational performance. More precisely, performance measurement is the set of deliberate activities for quantifying performance and the results of these activities is performance information [16]; its primary objective is to specify broad and abstract goals and missions to enable evaluation in order to identify where change is required to support improved performance [17]. Successful performance measurement systems are often characterized by being purposeful, unified, integrated, and flexible [18, 19]. Performance can be addressed at different level following the micro, meso and macro level distinguishing

between the system or policy sector, the chains and network (like clinical networks) and the individual or organization performance (like single hospital). Nonetheless, in the healthcare domain, complex patterns deriving from multi-level intersections may blur such clear configuration posing challenges to performance measurement [20]. Considering the micro level, performance measurement have evolved from a simple monitoring system to a valuable strategic decision-making information tool supporting managers in their strategic management and problem-solving activities, and also as a tool to facilitate communication [21]. In the dynamic hospital environment, performance measurement systems must continuously evolve to incorporate new and emerging information needs. As healthcare systems face rapidly changing challenges, such as advancements in medical technology, shifting patient demographics, evolving treatment protocols, and increased regulatory requirements, the metrics used to assess performance must also adapt. This may involve integrating new data sources to ensure that the system remains relevant and responsive. Furthermore, these systems must be flexible enough to address multidimensional information needs, such as the traditional financial and clinical outcomes, as well as patient-centered measures and sustainability, aligning with the evolving expectations of stakeholders, policymakers, and patients. In this regard, the growing emphasis on environmental sustainability as a strategic dimension in the healthcare domain requires its inclusion in performance management and measurement systems.

Sustainability as a key performance dimension in healthcare

In the pursuit of advancing healthcare systems and aligning them with global sustainability goals, the integration of sustainability principles into performance evaluation and management systems for hospitals and healthcare organizations has emerged as a critical area of interest. Understanding and measuring sustainability in healthcare involves addressing environmental, social, and economic dimensions (Fig. 1), to ensure that healthcare practices are not only effective but also environmentally

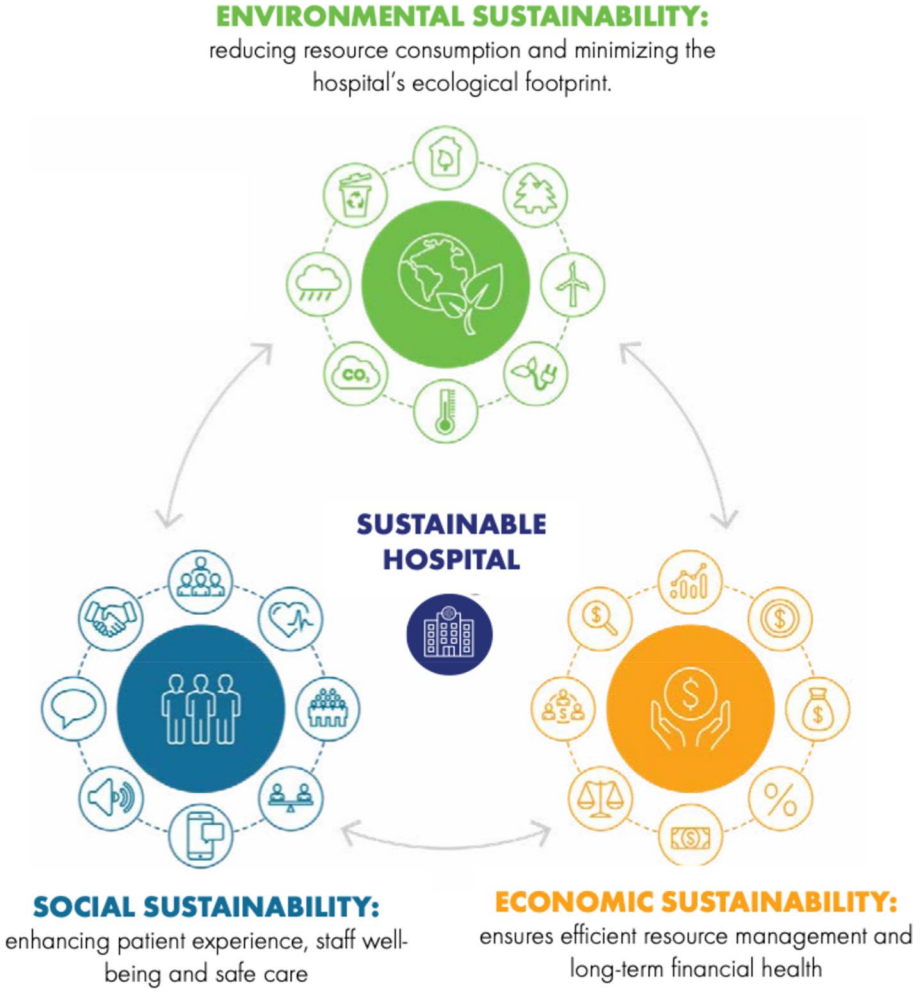

Fig. 1 Key sustainability dimensions for hospital facilities (developed by the authors)

responsible, socially equitable, and economically viable [22]. In addition to the three traditional dimensions identified, a fourth dimension—political sustainability—has emerged as crucial, particularly in countries with universal healthcare models, where healthcare policy is closely linked to public consensus [23]. Political sustainability relates to the ability of health system and organizations to secure and maintain the trust and support of both policymakers and citizens also considering the inclusion of participatory governance models – i.e. direct involvement of the population—in decision-making [24].

Among the sustainability dimensions, the economic aspect has been extensively studied and monitored as a strategic and viable component of health organizations, while environmental, social, and political sustainability have received comparatively less attention. As already stated, the dimension of environmental sustainability is gaining increasing prominence as a fundamental aspect of quality in healthcare, as noted by several scholars [6, 7, 25, 26]. The topic has been profoundly influenced by the seminal publication by World Health Organization [27], *Healthy Hospitals, Healthy Planet, Healthy People: Addressing Climate Change in Health Care Settings*, which significantly accelerated both political and scientific research on environmental sustainability in the healthcare sector. While the call for environmentally sustainable strategies is growing, actual progress in implementing these actions remains slow and uneven. As noted by Padget and colleagues [4] a meaningful shift can be achieved by embedding environmental sustainability into performance management systems, which help to conceptualize, prioritize, and operationalize the functions and goals of the healthcare systems and organizations. Efforts to incorporate environmental sustainability as a key domain for assessing healthcare systems are already underway. Examples include the Partnership for Global Health Resilience and Sustainability, which incorporated environmental sustainability as a key domain for assessing healthcare systems, particularly in the context of Italian regional systems [28] or the Care Quality Commission in England, which recently added environmental sustainability to its list of quality evaluation.[1]

Within the complex healthcare system, hospitals represent the most complex facilities in terms of intensity of care, occupancy rate and building complexity [29] and they represent the second highest energy consumption per unit area (KWh/m^2) among all industry sectors [7]. Therefore, an environmentally sustainable hospital can be defined as a green and healthy facility that promotes public health, while at the same time it minimizes its environmental impact and the resource consumption.

Over the course of time, the assessment of environmental performance has historically received low attention from healthcare administrators and clinical practitioners [7] and also from hospital accreditation organization (in 2023 the Joint Commission decided to make its environmental sustainability metrics optional after hospitals and health systems argued that the topic was not relevant when dealing with more urgent issues). Nonetheless, various green initiatives have been implemented at different levels within healthcare organizations to reduce waste, water consumptions, energy usage, and emissions [30]. However, these are often standalone actions, not integrated into a structured environmental sustainability hospital strategy supported by a performance measurement system.

Study aims

This research aims to understand the existing research in the area of environmental sustainability performance measurement for hospital facilities, and to identify criteria, metrics or indicators in the literature used to assess the performance of healthcare facilities in this domain. Additionally, the study proposes an evaluation model based on a critical review of the analyzed performance models and provides research avenues to support the integration of environmental performance into healthcare organizations' performance management system.

Despite the growing discourse on the environmental impact of healthcare organizations, there remains a lack of comprehensive understanding and analysis concerning the measurement of environmental performance in healthcare facilities, particularly within the broader context of performance management systems. In pursuit of this objective, the paper addresses the following research questions:

RQ1: What are the main environmental performance measurement tools for healthcare organizations?
RQ2. What are the main dimensions, criteria and indicators identified relations to environmental performance?

Research gap

Following the WHO report [27] that accelerated the debate on environmental impact of the healthcare facilities, in 2014 McGain and Naylor published a comprehensive literature review on the environmental impacts in hospital settings [7]. This research addresses the first limitation highlighted in the 2014 systematic review: the measurement of environmental performance in healthcare facilities. While previous studies identify key areas of impact, there is a lack of performance indicators and

[1] Care Quality Commission. Environmental sustainability—sustainable development. 2023. https://www.cqc.org.uk/assessment/quality-statements/well-led/environmental-sustainability.

measurement frameworks. Rather than providing specific performance indicators available in the literature, previous publications emphasized the key dimensions of sustainability performance. This study advances the scientific debate on the topic by contributing to the development of an evidence-based framework specifically designed to measure and enhance sustainability in hospitals. Moreover, significant gaps persist in identifying functional units and performance indicators that are tailored to the unique operational characteristics of hospitals, such as their high resource intensity and complex infrastructure, the strict regulatory requirements and the need to ensure safety and comfort to patients and healthcare workers. These operational constraints make general environmental assessment models insufficient for capturing the complexity and needs of hospital environments. By introducing a performance-based approach and systematically identifying Environmental Key Performance Indicators (EKPIs), this review addresses these shortcomings and offers a structured pathway for sustainability evaluation in hospital facilities.

The article has been organized according to the following sections: 1. Introduction; 2. Methodology of the review; 3. The results of the revised papers with the main findings on environmental performance dimensions; 4. The discussion of the findings, which includes the proposal of a set of EKPIs, developed from the literature; 5. Conclusions, highlighting the practical implications and suggesting future research areas.

Materials and methods

To gain a comprehensive understanding of the existing literature in this field, the authors have employed a Scoping Literature Review (SLR) to accomplish a comprehensive and structured synthesis of existing research on sustainability performance in hospital facilities. The method was selected to clarify the concept and assess whether previous studies have effectively measured performance in this context. The chosen methodology aligns with the research objective, which seeks to identify evidence and concepts within the existing body of literature [31]. By mapping the current scientific landscape, the review identified areas of measurement, provided an initial systematization of the scholarly discourse, and laid the groundwork for a future research agenda. The methodology framework adopted for the scoping review relies on the works proposed by Levac and colleagues, starting from the foundational paper by Arksey and O'Malley [32, 33].

Table 1 Research strategy

Level	Key words
Population	performance OR "performance management" OR "performance measuring" OR "performance indicators"
Concept	environment OR "environmental sustainability"OR "environmental impact" OR"environmental footprint"OR"ecological sustainability"
Context	"hospital facilit*"OR"hospital infrastructure"OR"hospital design" OR "hospital management" OR "hospital organization" OR "healthcare design" OR "healthcare management"

Step 1. Literature search

The search strategy was executed considering, three sets of keywords (Table 1) and performed in three databases: Scopus, WoS and PubMed. The first search criteria, pertains to the performance management and measurement. The second research field is identified with environmental sustainability in which environmental performance are to be investigated. As regards environmental sustainability the study refers to the terms, in line with the United Nations (UN) definition of sustainability, as the responsible management of natural resources to fulfil the current needs without compromising the ability of future generations to meet theirs [34]. For this reason, the study refers to environmental impacts in terms of resource consumption (input) or natural depletion and emissions (output). The last research field defines the context, with healthcare facilities, namely hospital to be identified as the facility addressed by the research. The keywords were delineated on three distinct levels and interconnected using Boolean operators (see Appendix 1 for the detailed research query). The search was performed on titles and abstracts. The search was filtered for English-full text original research articles and proceedings published in peer reviewed journals, while narrative reviews and meta-analyses were excluded. These studies have been excluded to focus on empirical research providing directly original and directly applicable performance indicators and methodologies, thus ensuring that our synthesis resulted in actionable, evidence-based metrics rather than generalized findings on the topic. All scientific articles published from 2009 to the present were selected. The year 2009 was chosen as the starting point because it marks the publication of the World Health Organization's study"*Healthy Hospitals, Healthy Planet, Healthy People: Addressing Climate Change in Health Care Settings*,"which brought the issue to the forefront of scientific and institutional debates. The literature search was last run in June 2024. The review has been conducted with the adoption the PCC strategy [35] – population (P), concept (C), context (C) – to define the criteria for selecting articles, with (P) as performance indicators; (C) environmental sustainability and (C), hospital environment.

Two independent authors (MD e AB) investigated the relevance of the papers obtained from the initial search by screening the titles and abstracts. The full text of the published literature was obtained if either reviewer

identified a contribution as potentially relevant. In the second phase of screening, both reviewers independently reviewed the full-text version of all included articles. Any discrepancies between reviewers were discussed until a consensus was reached. Records were screened for inclusion on the basis of predefined criteria. Contributions were considered for inclusion were required to meet the following criteria: (i) they focused on the hospital context, scientific articles or reviews concerning different healthcare and architectural types were excluded, as were those concerning specific healthcare areas (e.g. operating room, intensive care) or specific healthcare procedures/disciplines (e.g. laparoscopic surgery); (ii) they focused on the theme of environmental sustainability: articles or reviews specifically addressing other aspects of sustainability, such as economic or social sustainability, were excluded; (iii) they focused on multiple environmental impacts: publications focusing exclusively on a single environmental impact (e.g. energy consumption, waste management) were excluded, as they did not provide information regarding the establishment of a comprehensive environmental performance monitoring system for healthcare facilities; and (iv) they focused on performance measuring: articles or reviews emphasizing the measurement of environmental impacts were considered.

Additionally, for the purposes of this contribution, another exclusion criteria has been introduced, in relations to studies utilizing the Life Cycle Assessment (LCA) methodology and presenting the results of LCA studies. LCA studies have been excluded from this review as their methodological focus—on product- or process-specific environmental impacts across the life cycle—differs from the objective of identifying standardized, operational performance indicators applicable at the organizational level. Moreover, their methodological complexity and limited scalability reduce their relevance for routine analysis, and comparable environmental performance monitoring across diverse healthcare settings [36, 37].

The literature search yielded 545 potentially relevant publications. To refine these results, several inclusion and exclusion criteria were implemented, as outlined in Fig. 2. The PRISMA chart outlines the flow of information through the different phases of the review and highlights the reasons for exclusion. After exclusion, 22 relevant studies were included for the review.

Results

To answer RQ1, this section presents a descriptive analysis of the selected literature on environmental performances measurement in hospitals and healthcare facilities (Table 2). The literature review includes 22 studies, classified into three typologies: Original Articles

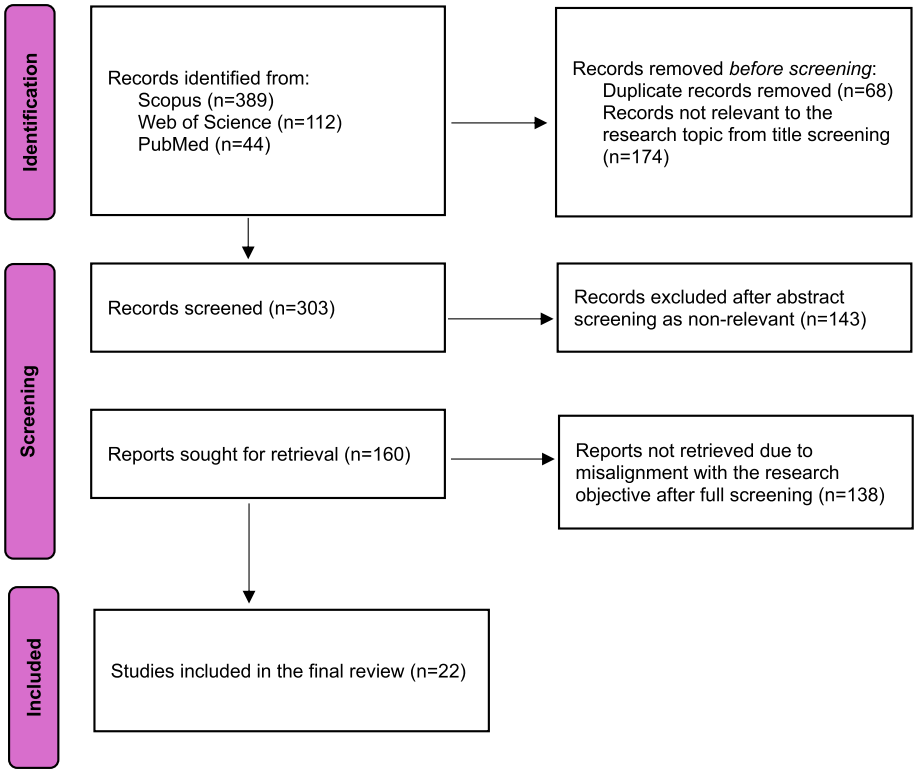

Fig. 2 PRISMA chart

Table 2 Publications included in the final review and key findings

Title and Year	Authors	Key findings
1. Sustainability in Healthcare: Combining Organizational and Architectural Levers (2012)	[38]	The contribution does not provide specific environmental KPIs, but focuses on the levers influencing sustainability performance. These include building design features (e.g., use of sustainable materials, daylighting, layout) and organizational elements (e.g., leadership, training, employee engagement). The study emphasize that sustainability initiatives fail when architectural innovations are not aligned with organizational culture and operational practices. Integration between infrastructure and organizational processes and behaviors is essential for improving hospital environmental performance
2. Sustainable Healthcare: How to Assess and Improve Healthcare Structures' Sustainability (2013)	[39]	This study proposes an integrated evaluation system for assessing the sustainability of healthcare facilities, considering environmental, economic, and social dimensions. The authors develop a multidimensional tool based on the Analytic Network Process (ANP), incorporating both qualitative and quantitative indicators. In terms of environmental performance, the model assesses domains such as energy use, water management, materials, waste, and urban integration. A key contribution is the development of a flexible, easy-to-use decision support tool that can be applied to both existing hospitals and new designs. This approach allows for the identification of critical areas and prioritization of strategic sustainability interventions. The study also emphasizes the importance of user perception and multidisciplinary evaluation in improving hospital sustainability
3. Environmental sustainability in hospitals – a systematic review and research agenda (2014)	[7]	The paper presents a foundational review of environmental sustainability in hospitals, emphasizing the urgent need for robust, measurable, and actionable performance indicators. The authors identify a significant lack of standardized and consistent metrics across healthcare facilities, noting that existing research predominantly focuses on operational aspects such as energy use, water consumption, and waste generation, while largely overlooking upstream and downstream impacts like supply chains or patient mobility. for a shift toward more holistic and integrated frameworks that can capture the complexity of hospital operations, highlighting the importance of interdisciplinary collaboration. Moreover, the study points to data scarcity and inconsistent reporting practices as major barriers to benchmarking and performance improvement, ultimately calling for systemic change in how environmental performance is measured and managed in the healthcare sector
4. Measuring environmental performance in hospitals: a framework and process (2016)	[40]	The study presents a structured framework for assessing environmental performance in hospitals, grounded in international standards such as the Global Reporting Initiative (GRI). The framework, tested in ten Brazilian hospitals, addresses key environmental domains including energy, water, emissions, waste, and transport. Organized into three phases—conception, implementation, and analysis—it supports hospitals in setting strategic objectives and translating them into operational indicators. The study highlights the lack of standardized, formal tools for environmental monitoring in healthcare and emphasizes the importance of clear, measurable indicators to improve regulatory compliance and drive continuous sustainability improvements
5. Measuring environmental performance in hospitals: a practical approach (2016)	[41]	The study proposes a structured, process-based framework for measuring environmental performance in hospitals, developed through a literature review, regulatory review, and empirical research in Brazilian healthcare facilities. It identifies the lack of strategic focus and formal frameworks as major limitations in current hospital environmental performance measurement efforts. The proposed framework integrates environmental dimensions from the GRI (Global Reporting Initiative) and Brazilian legislation. It includes indicators linked to specific organizational goals, deployed across strategic, tactical, and operational levels. The testing phase in six case studies showed the framework's feasibility, usability, and utility. It facilitated goal-setting, action planning, and indicator development, and led to improved communication, awareness, and compliance with environmental regulations
6. Managing Environmental Sustainability in Healthcare Settings (2017)	[42]	This paper emphasizes the importance of robust water and waste management practices in hospitals, identifying key operational areas with disproportionately high resource consumption. It highlights that while sustainability awareness is growing, hospitals often lack systematic tools and clear performance indicators. Carbon footprint assessment is discussed as a useful methodology for identifying emissions hotspots, particularly in energy use and waste management processes
7. Environmental Impact Reduction as a New Dimension for Quality Measurement of Healthcare Services (2018)	[43]	The study highlights the relevance of incorporating environmental metrics into clinical quality assessments and suggests that tools for environmental evaluation should be embedded into broader hospital performance management systems. Additionally, the paper illustrates that significant environmental impacts arise not only from direct energy use but also from upstream and downstream processes (e.g., equipment production, patient travel)
8. Environmental Performance Measurement in Hospitals: A Bibliometric Review of Literature (2018)	[5]	In this contribution the authors conducted a bibliometric review of literature spanning from 1987 to 2017, identifying significant gaps in frameworks specifically designed for measuring hospital environmental performance. Although research on environmental sustainability in hospitals has gained attention, few studies have proposed comprehensive, standardized performance measurement systems. Most existing frameworks and indicators are fragmented or isolated, lacking integration into holistic assessment tools, particularly for developing countries. This study emphasized the need for systematic approaches to evaluating environmental impacts in hospital settings, highlighting that effective measurement frameworks remain an unresolved challenge
9. Environmental Management in German Hospitals: A Classification of Approaches (2020)	[44]	The contribution emphasizes that environmental management maturity is associated with dedicated structures (e.g., environmental officers), environmental training, and stakeholder engagement. Implementation of certified EMS systems like ISO 14001 or EMAS is shown to improve environmental performance. The contribution calls for stronger top-down governance and financial incentives to enhance sector-wide environmental sustainability

Table 2 (continued)

Title and Year	Authors	Key findings
10. From bandages to buildings: Identifying the environmental hotpots of hospitals (2021)	[3]	The contribution identifies significant variation among hospitals and recommends prioritizing energy-efficient buildings, sustainable catering practices, and optimized resource use as key areas for improvement. The authors advocate for system-wide implementation of LCA methodologies to guide environmental strategies in healthcare. The contribution focuses on the performance of healthcare services in terms of carbon footprint
11. Principles for the Sustainable Design of Hospital Buildings (2021)	[45]	The paper emphasizes that hospitals should integrate energy-saving technologies, renewable energy sources, and resource-efficient materials to minimize ecological footprints. Key practices include designing buildings to leverage natural lighting, ventilation, and sustainable landscaping, as well as incorporating waste reduction and recycling measures. Sustainable hospital designs also consider environmental compatibility, such as minimizing toxic emissions and effectively managing hazardous waste to support overall environmental health and performance
12. Testing of a Multiple Criteria Assessment Tool for Healthcare Facilities Quality and Sustainability: The Case of German Hospitals (2022)	[46]	The study introduces an assessment tool for sustainability in healthcare facilities, a multiple-criteria assessment framework developed to evaluate the sustainability performance of healthcare facilities. Environmental indicators assessed include energy use, water consumption, waste production, transport, emissions, and site sustainability. The tool was applied in several German hospitals and proved useful for identifying strengths and weaknesses in environmental performance. The authors highlight the importance of integrating such tools into hospital governance processes to support informed, sustainable decision-making
13. Importance of hospital facilities management performance indicators: Building practitioners' perspectives (2022)	[47]	The contribution examines the importance of performance indicators (KPIs) in hospital facilities management (FM) from the perspectives of building practitioners. It identifies 18 KPIs categorized into physical, safety, environmental, and financial aspects, which were evaluated through a questionnaire survey conducted with hospital sector professionals in Hong Kong. The study reveals that physical and financial indicators, such as the availability of lift systems and fire services, are considered more important by practitioners compared to safety and environmental indicators. Significant differences were found between the views of different groups of practitioners), particularly regarding the importance of energy utilization and carbon emissions. The paper suggests further research to determine the importance weighting of each indicator and to test their applicability in real-world hospital settings
14. Modelling the Factors in Implementation of Environmental Sustainability in Healthcare Organizations (2023)	[48]	The study identifies critical factors influencing environmental sustainability in healthcare organizations, including green building initiatives, water consumption, resource usage, renewable energy, staff behavior, procurement of goods, hospital design, waste treatment methods, management of hazardous substances, air pollution, energy conservation, and environmental friendliness. The authors highlight the hierarchical interrelationships among these factors, emphasizing green building initiatives, renewable energy, resource efficiency, and water conservation as foundational elements that strongly drive the overall environmental performance. Moreover, the findings stress the importance of staff awareness and behavior as pivotal elements that facilitate the effective implementation of sustainability initiatives across hospital operations
15. Hospitals management transformative initiatives; towards energy efficiency and environmental sustainability in healthcare facilities (2023)	[49]	The contribution focuses more on energy performance, with limited exploration of other sustainability factors. The research proposes a roadmap for integrating ISO 50001-based Energy Management Systems (EnMS) in hospitals and highlights the importance of managing HVAC systems, employing smart technologies (e.g., IoT), and improving building envelope performance. Key environmental performance indicators used include energy consumption per patient bed-day, CO_2 emissions, and the proportion of renewable energy sources. The findings suggest that organizational commitment and cross-disciplinary collaboration are essential for successful energy performance improvements in healthcare facilities
16. Readiness of Agile-Sustainability in Healthcare Organizations (2023)	[50]	The study emphasizes the concept of agile sustainability as the ability of healthcare organization to adapt quickly to changing environments while ensuring that operations remain sustainable over time. The study highlights the importance of integrating sustainability into operational policies and practices in healthcare. Specifically, sustainability in healthcare is linked to the efficient use of resources, minimizing waste and maintaining service quality, all of which contribute to environmental performance
17. Life Cycle Sustainability Assessment of Healthcare Buildings: A Policy Framework (2023)	[51]	The study conducted a comprehensive Life Cycle Sustainability Assessment (LCSA) on public hospitals, comparing their performance with LEED-certified hospitals. It identified factors contributing to poor environmental sustainability, such as inefficient management, suboptimal planning, high energy consumption, and traditional construction practices. The study emphasizes the need for sustainable construction practices, adoption of renewable energy sources (e.g., solar energy), effective waste management, water and energy conservation, and using environmentally friendly materials. Additionally, it highlights social sustainability elements, including indoor air quality, thermal comfort, lighting, acoustics, and patient safety, as integral components of sustainability in healthcare infrastructure

Table 2 (continued)

Title and Year	Authors	Key findings
18. Identifying Environmental Impact Factors for Sustainable Healthcare: A Scoping Review (2023)	[52]	The paper is a very relevant contribution in the field, proving, which highlights the diverse environmental pressures caused by healthcare activities, focusing on waste generation, pollutant emissions and resource use. The study identifies 360 unique impact factors drawn from 46 articles, illustrating how healthcare activities affect the environment across various settings, such as hospitals, primary care, and mental health services. The factors were categorized using a Healthcare Environmental Impact Factor (HEIF) scheme, which provides a structured framework for selecting measurable indicators. The findings emphasize the need for standardization in environmental impact measurement, suggesting that future research could focus on refining these indicators, facilitating comparisons across healthcare organizations, and addressing gaps, such as the impact of chemicals and radiation. The paper also underscores the importance of integrating these factors into quality management practices to promote sustainable healthcare practices
19. Hospital sustainability indicators and reduction of socio-environmental impacts: a scoping review (2023)	[6]	This scoping review compiles a wide range of sustainability indicators used in hospitals, focusing particularly on water and energy consumption, waste generation, and emissions. It emphasizes the role of healthcare workers—particularly nursing staff—in influencing sustainable outcomes. However, it also identifies a persistent lack of standardized, hospital-specific sustainability metrics, which hinders comparability and progress tracking across institutions
20. Environmental sustainability in health care: An empirical investigation of US hospital (2023)	[53]	In this empirical investigation of U.S. hospitals, the study assesses various aspects of environmental sustainability, including energy efficiency, waste and water management, and emissions reduction strategies. The findings reveal that implementation of sustainability practices remains limited, with significant variability across institutions. The lack of standardized performance indicators and benchmarking tools is identified as a critical barrier. The paper calls for enhanced regulatory and policy support to foster the systematic adoption of environmental sustainability initiatives in hospital settings
21. Indicator-based environmental and social sustainability assessment of hospitals: A literature review (2024)	[36]	The paper is the most aligned with the scope of the literature review publications, in terms of performance indicators for sustainability in hospitals. The review analysis over 500 indicators, structured around environmental, social and governance and management dimensions. Crucially, the review identifies clear thematic gaps, notably the limited attention to upstream and downstream impacts within hospital supply chains. Given that the contribution does not provide a list of KPIs to be used for measuring and compare different facilities of the same facility across time, while it provides an extensive analysis of the main dimensions for environmental performance assessment
22. Green Hospital Face to Climate Change: Between Sobriety and Resilience (2024)	[54]	The study underscores that hospitals are both vulnerable to and responsible for climate-related and contributes significantly to national carbon emissions—up to 8% in the French healthcare sector. It introduces the concept of the "Green Hospital," which integrates environmental sustainability across the full life cycle of healthcare infrastructure, from design and construction to operation and decommissioning. Moreover, the hospital environment is analyzed for its capacity to reduce emissions through efficient water management, reduction in chemical use, responsible waste and plastic handling, and eco-conscious food and cleaning product procurement. According to the most recent observed trends, this recent contribution addresses sustainability with an holistic approach, discussion substantial cost savings from green initiatives, such as waterless surgical scrubs and efficient waste management, while acknowledging major barriers including high energy demands, infection control protocols, cultural resistance, and financial constraints. Ultimately, the author advocates for a reformation of healthcare systems toward greener models

($n = 14$), Literature Reviews ($n = 6$), and Case Studies ($n = 2$).

Geographical distribution of the contributions

The 22 studies included in this review cover a wide range of geographical locations, reflecting the global nature of the research on sustainability in healthcare facilities. Several studies originate from Europe, which emerges as a key region in the development of sustainable healthcare frameworks ($n = 9$). European publications provide the most comprehensive discussion on healthcare practices and sustainable design, with case study analysis in the sustainability field. Notably, Italy is a central contributor with multiple papers focusing on the integration of sustainability into healthcare structures, particularly in terms of building design and infrastructure [38, 39, 46]. Other areas also covered, with Brazil being the leading country for number of contributions ($n = 4$), showing a prominent focus on the mandatory regulatory framework for environmental sustainability. A significant share of contributions involves international collaborations, with contributions from authors affiliated with diverse countries and academic institutions [7, 47, 51]. These cross-border partnerships reflect the global nature of sustainability challenges in healthcare and enhance the depth and breadth of the research through the integration of varied perspective and expertise. This international coverage underscores both commonalities and regional differences in addressing sustainability challenges, particularly in terms of regulatory frameworks and mandatory measurement requirements.

Findings

Full-text analysis identified the main areas of performance related to environmental sustainability within the selected studies. Environmental sustainability performance include resource consumption reduction (*inputs*) and mitigation of impacts and emissions (*outputs*).

When environmental measures are included, they typically reference established regulations or ongoing sustainability initiatives [5]. The resource-oriented perspective has been employed to establish performance measures, focusing on criteria that address the depletion or consumption of environmental resources. The process of criteria definition focuses on identifying the domains in which performance indicators for environmental sustainability are established. To ensure robustness, domains recognized as performance criteria in at least five studies ($n = 5$) have been selected. These identified domains represent key areas with the most significant potential for enhancing the sustainability performance of healthcare facilities (Table 3).

The key metrics and function units adopted in the analysis of the different criteria and dimensions of Environmental Performance were extracted from the literature reviewed. These metrics were selected based on the frequency of use and alignment with the specific objective of performance measurement within each domain. The approach was evidence-driven, and these units reflect the operational scale and functional characteristics of healthcare facilities, ensuring relevance and comparability across diverse organizational and geographical contexts. The resulting EKPIs represent the metrics that best aligned with the scope and intent of performance assessment in each area.

Energy management and efficiency

The analysis of the literature reveals that energy management is a prominent critical dimension in environmental sustainability for hospital facilities. Indeed, energy management in hospitals is the most frequently discussed and impactful criteria for environmental sustainability performance. Hospitals are among the most energy-intensive infrastructures, consuming vast amounts of electricity and thermal energy for their operations [5, 43]. Multiple studies emphasize the need for performance metrics that capture energy intensity per unit area or per bed, allowing for cross-comparisons and benchmarking across healthcare facilities. For example, metrics like electricity intensity (kWh/m^2) and thermal energy consumption have been proposed to guide energy reduction strategies while maintaining operational effectiveness [5, 44].

Technological innovation and the progressive improving of energy performance in hospitals, with constant monitoring have been identified as the key dimensions [36, 40]. Several studies, including those by Blass et al. [56] and Galvão et al. [6], have highlighted the potential of hospital facilities to implement energy-saving technologies and operational improvements. Green building initiatives, such as the incorporation of energy-efficient systems and renewable energy production on-site, have shown significant promise in reducing energy intensity.

Renewable energy integration is increasingly highlighted, with some facilities achieving on-site production capabilities [3, 5, 39, 46, 49]. These initiatives are vital in reducing reliance on non-renewable energy sources, directly impacting greenhouse gas (GHG) emissions and operational costs. However, the adoption of energy-efficient technologies remains uneven, particularly in regions where capital investments are constrained [42].

Furthermore, energy efficiency initiatives often intersect with waste reduction and water management programs, demonstrating the interconnected nature of sustainability measures in hospitals [51]. Advanced modeling techniques, including Building Information Modeling (BIM), have been applied to optimize energy use, showcasing innovative strategies to reduce carbon footprints through better facility design and operational planning. Additionally, hospitals are implementing advanced HVAC systems and efficient lighting to lower energy intensity per square meter [5, 51].

Langstaff et al. [42], Brambilla et al. [46] and Blass et al. [5] explored the role of performance measurement systems in tracking energy use. The authors identified key

Table 3 Environmental criteria identified from the literature review

Energy Management (Energy Use, Energy Efficiency and Energy Supply)	[5–7, 36, 38–43, 46–49, 51–55]
Waste Management (Waste prevention and reuse, waster separations and recycling)	[3, 6, 7, 36, 38, 39, 43, 46, 53, 54]
Water Management (Water supply, Water Pollution and Water Use)	[6, 36, 39, 40, 42, 44, 49, 51, 53–55]
GHG Emissions (Climate Change Emissions)	[3, 7, 36, 40, 43, 44, 46, 49, 51, 53–55]
Transportation and Mobility (Transportation, Public Transport, Sharing and E-Mobility)	[42, 44, 46, 51, 54]
Site Sustainability (Site Selection, Design Facility Design)	[36, 38, 45, 46, 51, 54]

performance indicators (KPIs), such as electricity energy intensity (kWh/sqm) and renewable energy usage (%), as essential tools for monitoring progress and benchmarking hospital performance. Therefore, the integration of energy management practices into comprehensive sustainability frameworks requires harmonized indicators.

Waste management

Waste management is the second most frequently discussed criterion for environmental sustainability. Waste can be categorized into two types: general waste (i.e. solid urban waste not hazardous or not infectious, typically accounting for about 85%) and biomedical waste (i.e. hazardous and/or infective, radioactive or toxic waste, generally accounting for 15%). Pharmaceutical waste in hospital effluents presents a significant challenge, as local water treatment facilities are generally not equipped to properly manage this type of waste. Furthermore, there is a widespread lack of monitoring and measurement of pharmaceutical and chemicals contaminants in effluent streams [6, 52]. Studies emphasize the importance of standards and regulations in this area while also highlighting the need to go beyond existing, stressing the importance of education in waste segregation program for healthcare staff, as a key strategy to gain effective reduction of waste per capita and an increase in recycling rate. Measuring and tracking waste allows healthcare organizations to benchmark their performance against industry standards and set realistic goals for waste reduction. Similarly to energy management, performance in waste management can be assessed using functional units such as the number of bed (kg/day/bed), the square meter (kg/sqm/bed), or patient (head counts) [52].

Water management

The reviewed studies highlight the critical importance of water consumption and management in hospital sustainability, emphasizing the sector's significant role as a major consumer of water resources. Water is a crucial factor for clinical activities and hospital infrastructure management, which requires significant amount of water on a daily based. Several water-intensive activities, in terms of total value, represent the highest consumption in terms of m3/year/functional unit (FU) such as washing, sanitation, food preparation, processing and irrigation of external green areas. Studies introduced two key metrics to track water performances: water consumption per bed (m3/bed/year) and per total area (m3/m2/year), to ensure measurability and comparability [5, 36].

Langstaff et al. [42] and Seifert et al. [44] underline the need for robust water management strategies to address operational efficiency and environmental sustainability. The presence of water usage critical area within healthcare facilities, particularly in patient-care activities and sanitation, where consumption is disproportionately high has been highlighted [3]. Brambilla et al. [46] emphasizes the integration of water-saving technologies, such as efficient fixtures and recycling systems, into hospital infrastructure to mitigate water-related environmental impacts. Water is a critical input resource in sustainability performance evaluations, advocating for the inclusion of water consumption per patient or per bed as standard performance metrics [36, 52].

GHG emissions

The reviewed studies underscore the critical role of hospitals in mitigating their carbon footprint through targeted interventions and performance measurement frameworks and confirm the significant contribution of healthcare facilities to global greenhouse gas emissions, [3, 7, 42]. McGain and Naylor [7] emphasized that the healthcare sector accounts for a substantial proportion of global GHG emissions, largely due to energy use in heating, cooling, and lighting, as well as waste management and transportation. Their systematic review calls for the inclusion of GHG emissions as a core component in hospital sustainability assessment models. Similarly, Langstaff et al. [42] highlighted the potential of carbon footprint to identify resource-intensive area in hospital operations, particularly in energy generation and resource utilization.

Blass et al. [56] and Ullah et al. [51] both advocate for the integration of renewable energy sources as a primary strategy to reduce Scope 1 and Scope 2 emissions, which arise directly from hospital operations and indirectly from purchased electricity. Keller et al. [3] further identified the importance of energy-efficient systems and renewable energy adoption in reducing emissions from hospital facilities, particularly in high-energy demand areas like diagnostic imaging and HVAC systems.

Brambilla et al. [46] proposed GHG emissions tracking as a key performance indicator for hospital sustainability, emphasizing its relevance in monitoring progress toward climate goals. Their study included emissions per bed (ton/bed) and renewable energy sourcing (%) as critical metrics to quantify reductions. Galvão et al. [6] also highlighted the role of waste management and sustainable transportation practices in mitigating emissions, suggesting that hospitals integrate these activities into broader sustainability strategies.

Seifert et al. [44] and Esmaeili et al. [43] discussed the indirect emissions associated with supply chain operations and medical equipment manufacturing, arguing that a comprehensive GHG assessment must consider these upstream and downstream processes. However, their findings also revealed gaps in current methodologies, which often exclude these factors due to a lack of reliable data. Another dimension affecting GHG emission

performance is waste management. Studies emphasize that improving waste segregation and implementing recycling programs can significantly reduce a hospital's carbon footprint, particularly for waste disposal methods with high emissions potential [6, 54].

The studies collectively stress the importance of developing standardized measurement tools to track hospital emissions and benchmark progress across facilities. The adoption of international frameworks such as ISO 14064 for GHG accounting can provide consistency and comparability [52]. Moreover, the literature underscores the necessity of aligning hospital emission reduction targets with broader policy frameworks and global climate goals, ensuring that healthcare organizations contribute to sustainability efforts at a systemic level.

Transportation and mobility

The reviewed studies emphasize the critical role of transportation and mobility in the environmental sustainability of healthcare facilities, particularly in reducing carbon emissions and enhancing accessibility [3, 46, 53]. A recurring theme in the literature is the integration of sustainable transportation options, such as public transport accessibility, shared mobility services, and dedicated infrastructure for bicycles and electric vehicles, which contribute to reduced vehicular emissions and encourage eco-friendly commuting [42, 54]. For instance, Brambilla et al. [46] highlight the impact of mobility-sharing initiatives in hospital campuses, while Seifert et al. [44] focus on policies supporting public transit availability.

The inclusion of transportation indicators, such as proximity to public transport and the availability of e-mobility infrastructure, is considered essential in sustainability assessment models for hospitals [6, 51]. These indicators not only reduce the carbon footprint associated with hospital operations but also improve accessibility for patients and staff, fostering social and environmental sustainability. Despite the growing recognition of this dimension, many studies lack a comprehensive analysis of the interdependencies between transportation practices and hospital sustainability goals, leaving room for further investigation and integration of these strategies into broader performance measurement frameworks [38, 52].

Site sustainability

Localization criteria have emerged as a significant factor in sustainability strategies for hospital facilities. While they do not directly align with the operational performance of hospital organizations, they are shaped by a preliminary assessment during the design stage. Site sustainability for healthcare facilities, particularly hospitals, involved the strategic planning and management of physical spaces to minimize environmental impact while enhancing the well-being of patients, staff, and the surrounding community. To reduce the environmental footprint of hospital buildings, the contributions analysed highlight the importance of sustainable materials and site selection. Research confirms that the total heated area significantly influences overall heat demand and connected energy consumption, which are key factor in healthcare's environmental impact [3]. Other critical aspects include the integration of green spaces and draining areas, such as permeable pavements, which are essential for effective stormwater management, reducing runoff, and preventing soil erosion, thereby protecting local water bodies and infrastructure [45, 46]. Sustainable use of external spaces, such as green roofs and walls, also contributes to insulation, reduces the heat island effect, and promote biodiversity. Implementing these strategies not only supports environmental sustainability but also aligns with health-focused initiatives by creating a more resilient and pleasant environment for all facility users. Research suggests that incorporating sustainable practices into the localization decision-making process for healthcare infrastructure can lead to substantial long-term cost savings, improved patient outcomes, and a reduced carbon footprint, underscoring their importance in modern hospital design and operation [45, 46].

Discussions of the results

The scoping review revealed that since 2009, there has been a growing body of publications addressing environmental sustainability in hospital performance measurement. In addition the papers included in the review, an increasing number of publications and conference contributions on specific dimensions of sustainability have been published in the last years [55, 57]. This upward trend can be attributed to various international declarations [58] and policy frameworks designed to promote climate-resilient and environmentally sustainable healthcare systems, calling for comprehensive actions across health system.

The research strategy employed in this study identified 22 peer-reviewed studies in English that describe or apply performance metrics for evaluating the environmental performance of hospitals. The literature review facilitated the identification of essential components of environmental sustainability in healthcare settings, serving as primary drivers for effective performance management. However, while this study provides valuable insights and contributions to the existing body of knowledge, notable gaps persist in the field. These gaps underscore the need for further research and the development of more comprehensive frameworks to advance sustainability practices in healthcare facilities.

In relation to Research Question (RQ1) the review reveals that, despite an increasing relevance of

sustainability in the healthcare section, no comprehensive or standardized environmental performance measurement tools were identified, rather than general frameworks for environmental assessment, that are not performance drive (ISO 14031). While some studies propose environmental performance indicators [36, 40], these indicators are typically presented in isolation and not integrated into a validated tool.

In relation to Research Question 2 (RQ2), the review identifies six key components of environmental sustainability in healthcare facilities, which can be considered foundational building blocks for environmental measurement systems at the organizational level. These components encompass efficiency strategies and practices related to both the planning and operational activities of hospital facilities, where environmental impacts can be generated either as inputs or outputs. The majority of attention is directed towards measuring and managing energy use and waste, as these dimensions not only have significant environmental implications but also exert a considerable influence on the economic sustainability of healthcare facilities—especially in the current global context of rising energy costs. In addition to energy and waste, water consumption and GHG emissions are frequently incorporated into environmental impact assessments, focusing on the broader objective of conserving natural resources. Transportation policies and practices also emerge as recurrent areas of environmental monitoring, highlighting the importance of sustainable mobility within healthcare settings. Lastly, the incorporation of green or site sustainability considerations into measurement frameworks is gaining prominence, aimed at optimizing the environmental performance of healthcare facilities while simultaneously generating social and economic benefits.

The reviewed studies reveal some limitations. First, in terms of the environmental dimensions considered, they fail to account for metrics that capture the indirect effect of the hospital sector on other economic sectors and across the broader production and value chain. Additionally, concerns regarding the environmental impact of the manufacturing of medical and clinical products remain unaddressed. To overcome these gaps, a more holistic and comprehensive sustainability framework should be promoted, one that extends beyond the immediate operational impacts of healthcare facilities and includes upstream and downstream processes within the healthcare supply chain. Such an approach would allow for a more accurate assessment of the full environmental footprint of healthcare organizations.

Second, the review highlights a notable gap in the literature regarding studies that integrate a comprehensive set of KPIs that account for the multiple environmental dimensions. While three contributions outline evaluation systems by specifying areas or criteria for assessment, they do not provide a multidimensional set of quantitative indicators for measurement [6, 53, 56]. Furthermore, the reviewed studies fail to present a harmonized and systematic performance measurement framework designed to address environmental sustainability at the hospital facility level.

Environmental Key Performance Indicators (EKPIs)

To advance the development of a more comprehensive and integrated environmental measurement system, this study proposes a standardized set of EKPIs for environmental sustainability within healthcare facilities. The proposed EKPIs are designed to serve as a unified measurement tool for assessing environmental performance (Table 4). This framework aims to provide healthcare managers with a robust set of performance metrics that enable the evaluation of environmental sustainability as a core component of quality in hospital management. According to the most widely adopted international standard for assessing environmental performance, ISO 14031, environmental performance indicators must be developed with the following key characteristics: relevance, measurability, comparability, and reliability. By standardizing these indicators, healthcare organizations can more effectively track progress, benchmark against peers, and align their operations with sustainability goals.

The most adopted functional units to measure environmental performance in hospitals are the unit area of the building, expressed in square meters. The reviewed literature highlights that the functional unit of square meters may not be the most appropriate for hospital buildings, as these facilities exhibit substantial variability depending on the specific healthcare services provided. Instead, the number of beds represents a more suitable and consistent parameter for comparative performance assessment [51].

Among the environmental sustainability criteria identified from the literature review, input factors pertain to materials, water, and energy, while output factors relate to waste generation and emissions.

Limitations

The methodology used for the scoping review, while robust and replicable, does present some notable limitations that impact the findings. Specifically, the review did not evaluate the quality and robustness of the scientific contributions reviewed. Additionally, it did not offer a complete list of all performance indicators proposed in the studies analysed, instead defining a subset of indicators based on main criteria and broad categories. Moreover, the review neglected to address the role and behaviors of healthcare professionals

Table 4 List of environmental KPIs for sustainability performance monitoring in healthcare facilities

Category	Description	Unit
Energy Performance	Percentage of energy sourced from renewable sources	%
Energy Performance	Renewable energy production capacity on-site	%
Energy Performance	Electricity energy intensity	kWh/sqm
Energy Performance	Thermal energy intensity	kWh/sqm
Energy Performance	Total Energy Intensity	kWh/sqm
Energy Performance	Energy Saving (kWh over a one-year period)	%
Waste Management	Percent of recyclable municipal waste	%
Waste Management	Waste generated per bed	ton
Site Sustainability	Green space ratio to total site area	%
Site Sustainability	Draining area on total parking area	%
Site Sustainability	Permeable outdoor area ratio to total site area	%
Transportation & Mobility	Sustainable mobility sharing services availability	yes/no
Transportation & Mobility	Proximity to public transport (within 300 m from entrance)	yes/no
Transportation & Mobility	Dedicated spaces for bicycles and light mobility ≥ 15% of staff	yes/no
Water Consumption	Water consumption per bed	m3
Water Consumption	Water consumption per square meter	m3
GHG Emissions	Greenhouse gas emissions reporting capability	yes/no
GHG Emissions	Emissions per bed	ton

and staff in mitigating the environmental impact of hospital facilities. Lastly, the literature review presents, as a limitation, its inclusion of studies covering diverse hospital typologies. Such variability can introduce significant differences in scale, care intensity, and operational complexity, potentially affecting the comparability of the findings.

Conclusions

The analysed publications offer a comprehensive understanding of environmental performance measurement within healthcare facilities. As interest in sustainable healthcare continues to expand, the development and integration of performance management systems that enhance environmental sustainability are becoming increasingly critical. Transitioning towards more climate-resilient healthcare systems necessitates building a broad consensus for revising and adapting existing quality and performance assessment frameworks. This review offers insights into the current body of knowledge and identifies the key environmental dimensions that hospital managers should prioritize and integrate into their decision-making processes. Unlike previous reviews that focused broadly on sustainability challenges or theoretical frameworks, this review takes a practical and actionable step by identifying specific, quantifiable KPIs across key environmental sustainability dimensions. This study advances the discourse on sustainable healthcare provision by proposing a structured set of EKPIs tailored to the hospital level. By addressing key environmental sustainability domains, it provides the foundation for more effective performance measurement and strategic decision-making. Indeed, when carefully selected and implemented, sustainability metrics can aid managers and policymakers in formulating strategies and planning activities accordingly, and they serve as important tools for setting goals, monitoring progress, and realigning organizational behavior. Furthermore, the widespread use and transparent availability of environmental results facilitate benchmarking processes across organizations and can contribute to enhance reputation, accountability and performance recognition [59]. The shortlist of EKPIs (Table 4) represents a balanced, literature-based approach, focusing on environmental areas where hospitals can make the most significant impact while ensuring that indicators are measurable and applicable across different types of healthcare facilities. Nonetheless, the literature review revealed a significant gap in the measurement of specific and quantitative performance indicators for environmental sustainability within the hospital setting, particularly in a holistic representation. This gap is especially evident in the limited examples of sustainability performance across upstream and downstream value chains (especially with regard to medical products) and their link to clinical decision-making processes. This gap underscored the need for a more systematic and broad approach to evaluate the environmental impact of hospital facilities, particularly in an era where sustainability is becoming increasingly critical across all sectors. The evidence also suggested that research in this field should adopt a more holistic and integrated perspective, exploring the interconnections between sustainability domains – such as the interplay between environmental, economic and social implications – to support the development of coordinated, system-level strategies for sustainability in healthcare facilities. Environmental sustainability should

be considered a foundational objective of healthcare systems, alongside other principles such as efficiency, equity, and resilience [4].

Practical implications

The set of the 18 Environmental KPIs can be used as an evaluation framework for healthcare managers and hospital planners to bridge the existing gap in sustainability measurement within hospitals. By providing a measurable and focused list of indicators, the framework offers a tool for monitoring and improving the environmental performance, ultimately contributing to sustainable healthcare and quality improvement. Data collection challenges are mitigated by the fact that the performance evaluation system is based on a selection of a limited set of KPIs, making it accessible to all healthcare organizations, regardless of hospital type or geographical location.

Further research

This research focused on identifying a set of indicators to evaluate the environmental performance of hospital facilities. For future research, the identified set of indicators should be validated across various institutions to assess data availability and to establish benchmark thresholds for benchmarking. In fact, a next phase of the research could involve measuring a sample of hospitals to assess their environmental performance, ensuring that the indicators are applicable across diverse contexts and comparable across institutions. First, testing the model provides insight into the practical challenges of data collection and indicator application in healthcare facilities with significant differences. Second, it enables a comparative analysis that can highlight disparities between institutions in different regions. Finally, the data collected can inform policy development and guide the implementation of standardized environmental performance metrics in healthcare systems. By defining quantitative thresholds based on benchmark analysis, the research could significantly contribute to the creation of an evidence-based framework to improve sustainability in hospital care. Furthermore, it would represent a fundamental advancement toward the integration of environmental considerations as a key dimension of quality assessment within hospital organizations, thereby advancing the global effort to reduce healthcare's environmental footprint.

Abbreviations

PMS	Performance Measurement Systems
EKPI	Environmental Key Performance Indicator
KPI	Key Performance Indicator
NPM	New Public Management
SLR	Scoping Literature Review
GHG	Green House Gases
EP	Environmental Performance
OECD	Organization for Economic Co-operation and Development
WHO	World Health Organization
FU	Functional Unit
BIM	Building Information Modelling
UN	United Nations
HVAC	Heating, Ventilation and Air Conditioning

Supplementary Information

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Supplementary Material 1.

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Authors' contributions

MD and FF contributed to the conceptualization, methodology, framework development, and writing, including review and editing. MD initially sorted the abstracts, which were subsequently reviewed by AB, who defined the inclusion and exclusion criteria and selected the final list of publications for full review. MD also led the development of the Environmental Key Performance Indicator (EKPI) list presented in the discussion section. SC supported the development of the methodological framework and, as a senior researcher, was involved in reviewing all sections at every stage of the project. All authors have read and approved the final manuscript.

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Data availability

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Declarations

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Competing interests

The authors declare no competing interests.

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