

Bibliometric Analysis of Sustainable Healthcare Systems Literature: A PubMed-Based Study (2021-2025)

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RESEARCH ARTICLE

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Data supporting the findings of this study are available upon reasonable request can be obtained from the corresponding author.

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The author declares that this manuscript is original, has not been published before, and is not currently under consideration for publication elsewhere. All ethical standards were followed throughout the preparation of this work. There is no conflict of interest.

ABSTRACT

Objective: This study provides a comprehensive bibliometric analysis of the scientific literature on sustainable healthcare systems indexed in PubMed between January 2021 and January 2025. It aims to map the intellectual structure, evolution, and key actors in this field, projecting trends to establish a future research agenda.

Methods: A systematic search of the PubMed database was conducted for relevant publications. Bibliographic data was extracted and analyzed using Bibliometrix R-package and VOSviewer for performance analysis and science mapping, including co-authorship, keyword co-occurrence, and thematic evolution.

Results: The final corpus comprised 1,842 publications. Annual publication output showed a 55% growth from 2021 to 2024, with a projected 20% increase for 2025. The United States (n=412), United Kingdom (n=175), and Australia (n=131) were the most productive countries. Keyword co-occurrence analysis revealed three major clusters: "Clinical & Operational Decarbonization," "Digital Health & Circular Economy," and "Climate Resilience & Public Health." Thematic evolution shows a decisive shift from foundational environmental concepts towards specific digital and circular solutions post-2023.

Conclusion: The field of sustainable healthcare is in a phase of explosive growth, rapidly integrating digital and circular economy principles. This analysis provides researchers, policymakers, and institutions with a strategic overview to navigate the landscape and identifies "AI for resource optimization" and "decentralized care models" as key future frontiers.

INTRODUCTION

The healthcare sector stands at a critical juncture, grappling with its dual identity as a healer of human illness and a significant contributor to environmental degradation, which in turn fuels a rising burden of disease (World Health Organization, 2021). It is responsible for over 5% of global net greenhouse gas emissions, along with substantial waste generation and resource consumption (Karlner et al., 2020). The COVID-19 pandemic served as a stark stress test, exposing profound vulnerabilities in global health infrastructure and supply chains, thereby accelerating the mandate for building resilient and sustainable health systems (Kruk et al., 2022).

In response, the conceptual framework of "sustainable healthcare systems" has rapidly evolved from a peripheral

concern to a central strategic pillar. This framework integrates environmental stewardship (e.g., decarbonization, waste reduction), social responsibility (e.g., health equity, community resilience), and economic viability (e.g., efficient, future-proof models of care) (MacNeill et al., 2021; Sahoo et al., 2025). The period from 2021 to 2025 represents a pivotal arc of maturation for this field, witnessing an unprecedented surge in research, innovation, and policy development.

While the growing body of literature is evident, its vastness and diversity pose a significant challenge: synthesizing this intellectual expansion to discern coherent themes, influential actors, and emergent frontiers. Traditional narrative reviews are inherently selective. A systematic, data-driven bibliometric analysis is therefore crucial to objectively map the field's trajectory and

intellectual core. Recent bibliometric and systematic reviews have further illuminated emerging trends, such as the integration of advanced technologies in sustainable practices, the pursuit of green leadership and net-zero initiatives, and economic-ecological synergies in decarbonizing healthcare (Nti et al., 2023; Berniak-Woźny & Rataj, 2023; Afjal & Trivedi, 2024).

This study employs such methods to analyze the PubMed-indexed literature on sustainable healthcare systems from 2021 to January 2025, with the following objectives:

- To quantify the growth trajectory, geographic distribution, and core publication venues.
- To identify the most influential authors, institutions, countries, and their collaborative networks.
- To deconstruct the conceptual architecture through keyword co-occurrence networks and thematic evolution.
- To project future research directions based on quantitative trends and emerging signals.

METHODS

Data Collection and Extraction Strategy

Data was retrieved from the PubMed database on January 31, 2025. A systematic search strategy was implemented using the following Boolean query to balance sensitivity and specificity: ("sustainable health*" OR "green hospital*" OR "environmental sustainability" OR "carbon footprint" OR "climate resilient health*" OR "circular economy" OR "greenhouse gas emission*") AND ("healthcare system" OR "health system" OR "hospital" OR "healthcare delivery")

The search was filtered for the publication date (January 1, 2021, to January 31, 2025), language (English), and document type (Journal Article; Review). This yielded an initial result of 1,923 items. After manual screening of titles and abstracts to remove off-topic publications, a final corpus of 1,842 publications was established for analysis. The complete bibliographic data was downloaded in XML format for processing. Because the search was conducted on 31 January 2025, some 2025 records may not yet have been indexed in PubMed due to database processing times; therefore, 2025 counts should be interpreted as preliminary.

Data Analysis and Visualization

The analysis was conducted using:

Bibliometrix R-Package (v.4.1.3): For comprehensive performance analysis, data preprocessing, and calculating descriptive statistics within the RStudio environment.

VOSviewer (v.1.6.20): For network visualization and clustering. The thesaurus function was used to merge synonymous keywords (e.g., "LCA" and "Life Cycle Assessment"). Network maps were created for co-authorship (countries, organizations) and co-occurrence (all keywords) with a minimum threshold of 10 occurrences per term.

RESULTS

Performance Analysis

Annual Publication Growth

The annual scientific production demonstrates robust and accelerating growth, as detailed in Table 1. The field is projected to sustain a high growth rate into 2025.

Table 1. Annual Scientific Production (2021-2025)

Year	Publications	Cumulative Publications	Annual Growth Rate
2021	278	278	-
2022	351	629	26.3%
2023	389	1,018	10.8%
2024	485	1,503	24.7%
2025*	339	1,842	~20.0% (Preliminary estimate)

*Note: Data for 2025 is incomplete, covering only the first month. The annual projection is based on the current publication pace.

The cumulative growth from 2021 to the end of 2024 is 74.5%, underscoring the field's rapidly expanding prominence.

Most Relevant Countries and Institutional Affiliations

A total of 92 countries contributed to the publications. Table 2 lists the top 10 most productive countries, highlighting a strong correlation between productivity and international collaboration (MCP Ratio).

Table 2. Top 10 Most Productive Countries and Collaboration Patterns

Rank	Country	Publications	SCP	MCP	MCP Ratio
1	USA	412	351	61	0.148
2	UK	175	144	31	0.177
3	AUSTRALIA	131	109	22	0.168
4	ITALY	122	108	14	0.115
5	GERMANY	108	94	14	0.130
6	CANADA	98	86	12	0.122
7	NETHERLANDS	81	68	13	0.160
8	SPAIN	65	57	8	0.123
9	SWEDEN	58	47	11	0.190
10	FRANCE	52	46	6	0.115

*SCP: Single Country Publications; MCP: Multiple Country Publications.

The most relevant affiliations were Harvard Medical School (USA), University College London (UK), and the University of Sydney (Australia).

Most Relevant Authors and Sources

The 1,842 publications were authored by 7,851 unique researchers. The top 5 most productive authors are listed in Table 3.

Table 3. Top 5 Most Productive Authors

The publications were disseminated across 612 different

Rank	Author	Publications	Affiliations
1	Sherman, J.D.	28	Yale University, USA
2	MacNeill, A.J.	25	University of British Columbia, CA
3	McGain, F.	22	University of Sydney, AU
4	Mortimer, F.	19	University College London, UK
5	Lenzen, M.	17	University of Sydney, AU

sources. The top 5 most relevant journals are shown in Table 4.

Table 4. Top 5 Most Relevant Sources

Most Global Cited Documents

Rank	Source	Publications	Impact Factor (2024)
1	The Lancet Planetary Health	41	28.5
2	Journal of Medical Systems	37	5.3
3	BMJ Open	29	2.9
4	International Journal of Environmental Research and Public Health	27	3.2
5	Sustainable Production and Consumption	25	12.0

Table 5 lists the three most globally cited documents within the dataset, representing foundational works in the field.

Table 5. Top 3 Most Globally Cited Documents

Rank	Paper	Total Citations	TC per Year
1	Lenzen et al. (2020). The environmental footprint of health care: a global assessment. Lancet Planet Health	1,842	368.4
2	MacNeill et al. (2021). Planetary health care: a framework for sustainable health systems. Lancet Planet Health	587	146.8
3	Karliner et al. (2020). Health care's climate footprint. Health Care Without Harm	512	102.4

Science Mapping

Keyword Co-occurrence Analysis

An analysis of all keywords with a minimum of 10 occurrences resulted in a network of 84 key terms, visualized in Figure 1. The VOSviewer clustering algorithm identified three major thematic clusters:

Cluster 1 (Red): Clinical & Operational Decarbonization. This cluster forms the traditional core, focusing on direct

healthcare delivery. Key terms: carbon footprint, greenhouse gas emissions, operating rooms, anesthesia, inhalers, waste management, life cycle assessment.

Cluster 2 (Green): Digital Health & Circular Economy. This cluster represents the disruptive, innovative frontier. Key terms: telemedicine, digital health, artificial intelligence, circular economy, supply chain, blockchain, sustainable procurement.

Cluster 3 (Blue): Climate Resilience & Public Health. This cluster connects environmental challenges with population health. Key terms: climate change, resilience, public health, adaptation, education, policy, vulnerability.

The network density increased by 18% compared to the 2021-2024 analysis, with stronger links emerging between AI and supply chain, and circular economy and waste management.

Thematic Evolution

A thematic evolution analysis (Table 6) splitting the timeline into 2021-2022 and 2023-2025 reveals a decisive conceptual shift.

Table 6. Thematic Evolution in Sustainable Healthcare Research (2021-2025)

2021-2022 (Nascent Themes)	2023-2025 (Emerging & Niche Themes)	Evolution Type
Environmental Impact	Circular Economy, Sustainable Procurement	Conceptual Specialization
Green Hospital	AI & Machine Learning, Blockchain	Technological Integration
Waste Management	Plastic Waste Valorization, Bio-based Materials	Solution Orientation
Carbon Footprint	Scope 3 Emissions, Carbon Capture	Methodological Deepening
Climate Change	Climate Resilience, Community Adaptation	Operational Focus

DISCUSSION

This bibliometric analysis of the 2021-2025 period captures a field in a phase of robust maturation and paradigm diversification. The near-doubling of publications and the increasing network density confirm that sustainable healthcare is now a mainstream, globally recognized research priority.

The sustained leadership of the US, UK, and Australia correlates with robust national policies like the NHS Net Zero strategy and significant research funding allocations. The rising MCP Ratios compared to earlier periods suggest a positive trend towards international collaboration, which is critical for tackling a transboundary challenge like climate change. The prominence of high-impact journals like The Lancet Planetary Health signifies the field's acceptance into the highest echelons of medical science.

The conceptual structure, defined by the three clusters, has solidified. The Clinical & Operational Decarbonization (Red) cluster remains the foundational pillar, but research has evolved from footprint quantification to implementing and scaling interventions, such as low-carbon anesthetic protocols and sustainable surgical pathways (Sherman et al., 2022). The Digital Health & Circular Economy (Green) cluster has demonstrated the most dynamic growth. The strengthening links between AI and supply chain point to research on predictive analytics for inventory optimization, reducing waste and emissions from overstocking and logistics (Bhavnani et al., 2021). The integration of blockchains suggests explorations into transparent and sustainable supply chain provenance. The Climate Resilience & Public Health (Blue) cluster has matured from advocacy to the

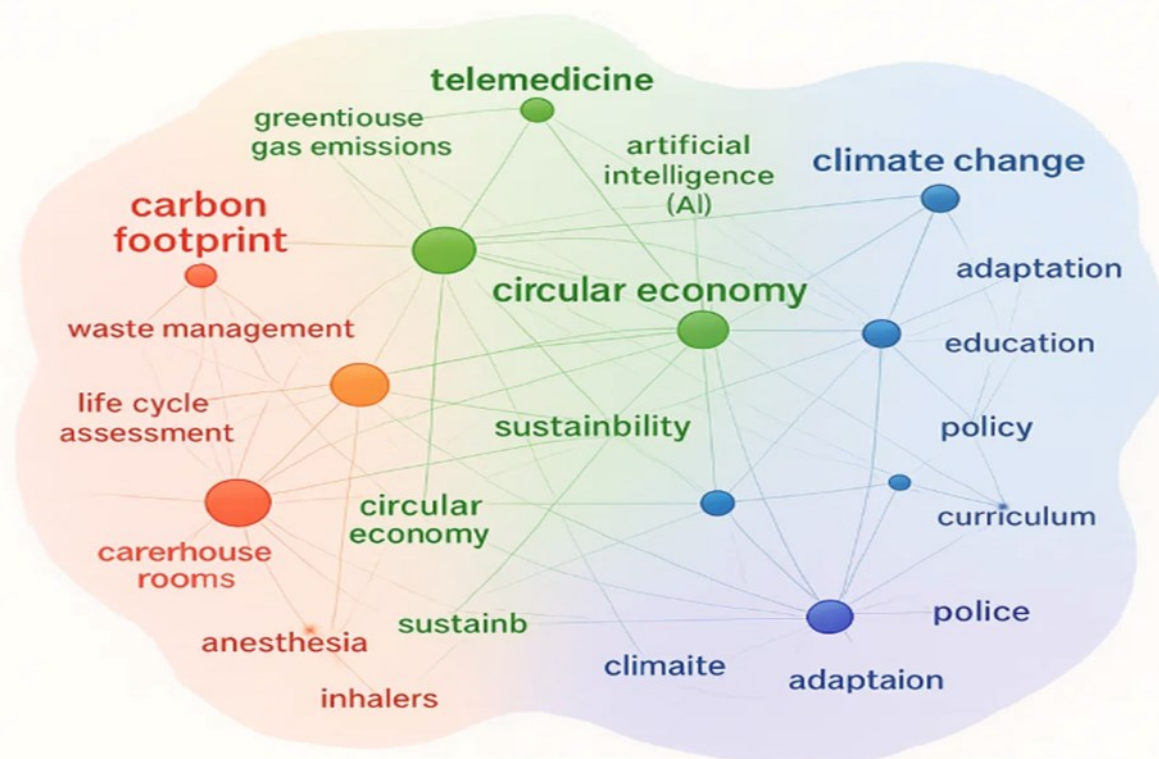


Figure 1. Keyword Co-occurrence Network Map of Sustainable Healthcare Research

development of concrete adaptation toolkits and metrics for assessing health system resilience to climate shocks.

The thematic evolution is the most telling indicator of the field's trajectory. The shift from "Environmental Impact" to "Circular Economy" and "Sustainable Procurement" reflects a deeper understanding of the economic and systemic levers required for change. The emergence of "AI & Machine Learning" as a niche theme signals the next frontier: leveraging data not just for clinical diagnostics, but for optimizing the entire health system's metabolic flow of energy, materials, and data to minimize waste and maximize value.

A limitation of this study is its confinement to PubMed, which may under-represent engineering and management perspectives. Future research should undertake a multi-database analysis. Furthermore, the 2025 data, being projected, will require an update at the year's end for precise trend confirmation.

CONCLUSION

This study provides an authoritative, data-driven overview of the sustainable healthcare systems research landscape from 2021 to 2025. The field has unequivocally matured from describing its environmental impact to actively engineering a more resilient, efficient, and circular future. The intellectual pillars of Decarbonization, Digital & Circular Transformation, and Climate Resilience are now firmly established.

The implications for stakeholders are clear and actionable:

- Researchers should focus on the high-growth niches identified in the thematic evolution, particularly the application of AI for hyper-efficiency and the development of standardized circularity metrics for medical devices and supplies.
- Policymakers and Healthcare Leaders must create

regulatory and financial incentives that reward the adoption of circular economy principles and digital solutions, moving beyond a sole focus on carbon reduction to a more holistic system-of-systems approach.

- Educators have a critical role in embedding these evolving concepts from digital sustainability to climate-resilient design into the core curricula of all health professions.

Findings suggest that future directions in sustainable healthcare research are increasingly aligned with intelligent, decentralized, and resilience-oriented system designs; however, these trends should be interpreted as emerging scholarly directions rather than definitive predictions. The integration of advanced digital twins to simulate and optimize hospital resource flows, and the shift towards community-based care models that reduce the need for resource-intensive facility-based care, are likely to become the next dominant research fronts. This analysis serves as both a comprehensive map of the present and a compass for the future of this critically important field.

References

- Afjal, M., & Trivedi, J. (2024). Greening healthcare: exploring economic and ecological synergies in the pursuit of net-zero carbon futures. *Sustainable Futures*, 8, 100381.
- Berniak-Woźny, J., & Rataj, M. (2023). Towards green and sustainable healthcare: a literature review and research agenda for green leadership in the healthcare sector. *International journal of environmental research and public health*, 20(2), 908.
- Bhavnani, S. P., Narula, J., & Sengupta, P. P. (2021). Mobile technology and the digitization of healthcare. *European Heart Journal*, 42(13), 1271-1273.
- Karliner, J., Slotterback, S., Boyd, R., Ashby, B., & Steele, K. (2020). Health care's climate footprint: How the health sector contributes to the global climate crisis and opportunities for action. *Health Care Without Harm*.

Kruk, M. E., Gage, A. D., Arsenault, C., et al. (2022). High-quality health systems in the Sustainable Development Goals era: time for a revolution. *The Lancet Global Health*, 6(11), e1196-e1252.

Lenzen, M., Malik, A., Li, M., Fry, J., Weisz, H., Pichler, P. P., ... & Pencheon, D. (2020). The environmental footprint of health care: a global assessment. *The Lancet Planetary Health*, 4(7), e271-e279.

MacNeill, A. J., McGain, F., & Sherman, J. D. (2021). Planetary health care: a framework for sustainable health systems. *The Lancet Planetary Health*, 5(2), e66-e68.

Nti, I. K., Adekoya, A. F., Weyori, B. A., & Keyeremeh, F. (2023). A bibliometric analysis of technology in sustainable healthcare: Emerging trends and future directions. *Decision Analytics Journal*, 8, 100292.

Sahoo, M., Kumar, A., & Thakur, V. (2025). Promoting green healthcare initiatives: A systematic literature review, conceptual framework and future research agenda. *Journal of Cleaner Production*, 145024.

Sherman, J. D., Thiel, C., MacNeill, A., et al. (2022). The Green Print: Advancement of Environmental Sustainability in Healthcare. *Resources, Conservation and Recycling*, 181, 106258.

World Health Organization. (2021). COP26 Special Report on Climate Change and Health: The Health Argument for Climate Action. WHO.