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Health systems' responses to climate change: an umbrella review of systematic reviews

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Systematic Review

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Abstract

Background

Climate change places increasing pressure on health systems. They must both reduce their negative impact on the environment and strengthen resilience to climate-related risks.

Objective

To synthesize and map the evidence from systematic reviews on the scope and effectiveness of climate change mitigation and adaptation actions in health systems.

Methods

An umbrella review of systematic reviews examining health system responses to climate change was conducted. The review followed the Joanna Briggs Institute methodological guidelines and adhered to the PRISMA checklist. The included systematic reviews had to meet two overarching criteria: at least two databases were searched, and a predefined instrument was used to assess the quality or risk of bias of the included studies.

Results

Thirty-nine systematic reviews published between 2020 and 2025 were included, covering 933 individual studies. Most reviews (35/39) focused exclusively on mitigation strategies, with evidence concentrated around major greenhouse gas emission hotspots: surgical procedures; radiology; pharmaceuticals; food waste; and transportation of patients and staff. Across these areas, many mitigation strategies were associated with environmental and economic co-benefits, although the underlying evidence was heterogeneous and often of low to moderate quality. In contrast, only a small number of reviews addressed climate adaptation and health system resilience.

Conclusions

Existing evidence provides practical guidance on effective climate mitigation actions. The limited number of systematic reviews on climate adaptation highlights a gap in the evidence base. Translating mitigation evidence into clinical guidelines and policies and strengthening research on adaptation could support more systematic climate action in health systems.

1. BACKGROUND

Climate change is the most significant threat to human health globally [1–3]. It negatively affects population access to basic human needs, such as clean air and water, increases the burden of climate-related risk factors and diseases, and alters patterns of disease transmission [3,4]. At the same time, the increasing frequency of extreme weather events (e.g., floods, hurricanes) disrupts health care delivery [3]. Consequently, climate change impacts health systems by simultaneously increasing the demand for healthcare provision and impairing their ability to respond. Current prognoses predict that more severe climate risks will emerge sooner than previously expected [5], putting an enormous pressure on health systems to implement adequate response strategies [6].

The health system response to climate change comprise two closely interdependent dimensions: 1) environmental sustainability, which aims at mitigating the negative impact of health systems on the environment by reducing its greenhouse gas (GHG) emissions, and 2) climate resilience, focusing on adaptations measures to better cope with the impact of climate-related shocks and stress [7]. Within both dimensions, a variety of actions can be implemented at different levels of the health

system, and their effectiveness can be assessed using diverse direct and indirect metrics (Table 1). The World Health Organization's (WHO) "Operational framework for building climate resilient and low carbon health systems" integrates both concepts into guidance on health system transformation [7].

Table 1
Conceptual framework of health system's response to climate change

Dimension	**Health system's response to climate change**	
	Environmental sustainability - MITIGATION	**Climate resilience – ADAPTATION**
Focus	reducing the negative impact of health systems on environment	better coping with the impact of climate change
Examples of actions	• changes in clinical practice to reduce greenhouse gas emission, • reducing low-value care, • investments in renewable energy sources, • more sustainable waste management, • reducing health workforce travel, • incorporating sustainability rules into procurement contracts	• implementing early warning systems, • planning back-up systems for service delivery during climate-induced disasters, • investing in climate-proofing of health infrastructure, • training the health workforce in disaster management
Examples of effectiveness measures	• reduction of greenhouse gas emissions (e.g. in kilograms (kg) per year or per specific health care service/product life cycle) • reductions in plastic waste or water usage per patient/procedure	• reduction in the number of deaths or people affected by climate-related disasters per 100,000 population, • reduction in heat-related excess mortality • reduction in frequency of healthcare provision disruption/infrastructure damage due to climate-related disasters
Source: Authors' own compilation		

Health system responses to climate change have emerged as an important priority for health policy and research [8]. Under the auspices of the WHO, The Alliance for Transformative Action on Climate and Health has brought together over 100 countries whose Ministers of Health have committed to strengthening the climate resilience of health systems and/or reducing their GHG emissions [9,10]. Research on health system response to climate change has expanded significantly, with numerous reviews published in the last two years (2024–2025), including systematic [11–16], rapid [17,18], scoping[19–22], integrative[23,24] and/or narrative [25,26] reviews. However, important gaps remain: Many systematic reviews focus only on a narrow aspect – for example environmental sustainability in a chosen medical discipline [11,16] or adaptation to heat related risks[15]. In contrast, rapid, scoping and narrative reviews typically cover a broader range of actions but they do not conduct quality and/or risk of bias assessments of the underlying evidence. For evidence-informed health policy, however, the quality of the research evidence is crucial.

To address these limitations, we conducted an umbrella review of systematic reviews on environmental sustainability and climate resilience actions in health systems, focusing on reviews that included a quality and/or risk of bias assessment of their underlying primary studies. Umbrella review are particularly valuable when several recent and still up-to-date systematic reviews on the topic are available [27]. Our main goal was to offer decision makers a comprehensive and policy-relevant overview of the available evidence on environmental sustainability and climate resilience actions[28,29]. More specifically, the objectives were to: 1) characterize the main features of existing systematic reviews; 2) map the scope of available evidence on

health system responses to climate change by geography, health system level, and type of response; and 3) synthesize evidence on the effectiveness of specific response strategies.

2. METHODS

The work followed the Joanna Briggs Institute (JBI) methodological guidelines for evidence synthesis in umbrella reviews [28,29] and adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist [30]. The review was registered in PROSPERO (CRD420251052647) [31], while its protocol was published in a peer-reviewed journal [32].

2.1. Review questions

Three specific review questions were defined: 1) What are the main characteristics of the published systematic reviews?; 2) What is the scope of the available evidence on health system response to climate change (by geography, health system level, and type of response)?; 3) What evidence exists regarding the effectiveness of particular response strategies?

2.2. Inclusion and exclusion criteria

We defined inclusion and exclusion criteria using the PICOS (Population, Intervention, Comparison, Outcomes, Study design) framework [33] (see Table 2). Broadly speaking, we included systematic reviews that examined health system responses to climate change, focusing on environmental sustainability and/or climate resilience. For both concepts, we applied the WHO definitions [1]. In addition, systematic review had to meet the following quality criteria: 1) at least two databases were searched, and 2) a predefined instrument was used to assess the quality or risk of bias of the included studies.

Table 2
Inclusion and exclusion criteria

Element	Inclusion	Exclusion
P - Population	Health system stakeholders at macro, mezzo, and micro levels (e.g. systematic reviews focusing on health systems as a whole or their subsectors e.g. hospital providers, general practice)	Studies with a primary focus outside the health system stakeholders (e.g., urban planning, agriculture)
I - Intervention	Health system response to climate change, captured within: I - environmental sustainability (e.g., actions aimed at reducing greenhouse gas emissions), and/or II - climate resilience (e.g. actions aimed at improving preparedness for climate-induced disasters), using WHO definitions	Studies focusing on the impact of the climate crisis on population health or changing disease patterns, changes in risk factors, changes in healthcare demand (e.g., increased hospital admissions). Studies that measure the impact of HS on environment (without offering solutions on how to limit the negative impact or without comparing which solution is less harmful for the environment). Studies addressing health system preparedness for non-climate-related disasters (e.g. terrorist attacks)
C - Comparison	Not applicable	Not applicable
O - Outcome	Outcomes of response strategies, including: I – environmental sustainability measures (e.g., decreased carbon footprint measured in CO2e kg/year or reduced plastic waste in kg) and or II - climate resilience measures (e.g. health facility safety index, or chosen population/ health system-level indicators of climate resilience as defined by WHO)	Studies that focus on attitudes, barriers and facilitators to the health system response to climate change without the analysis of strategies outcomes/effectiveness (e.g., reviews focused on medical professional education, curricula content)
S – Study design/type	Systematic reviews (or other types of reviews) that report on the quality/risk of bias assessment of the included studies Must be published in a peer-reviewed journal.	Any types of systematic literature reviews where quality assessment/risk of bias of the included studies was not conducted. Systematic reviews not published in peer-reviewed journals.

2.3. Search strategy

In July 2025, five databases were searched: 1) MEDLINE via PubMed, 2) Scopus, 3) Web of Science Core Collection, 4) ProQuest Central, and 5) Cochrane Database of Systematic Reviews. The search strategy was developed in accordance with the PRESS guidelines [34] and combined multiple terms related to climate change AND health system AND systematic review. Where available, a dedicated filter for systematic reviews was applied. Terms were searched as keywords in the title and/or abstract fields, and, when appropriate, Medical Subject Headings (MeSH) terms were also used. Prior to finalization, the strategy was tested across all five databases to ensure accuracy and relevance. We included studies published from 2015 onward, with full text available in English. Table S1 Supplementary File presents the full search strings for each database. In addition, the references of included studies were screened to identify additional systematic reviews that met the inclusion criteria.

2.4. Selection of studies

All records were downloaded and deduplicated using Rayyan software[35], which also supported the study selection process. This process involved two stages: 1) screening of titles and abstracts and 2) full-text assessment. Two researchers independently participated in both stages and evaluated the records/full texts according to the predefined inclusion and exclusion criteria (Table 2). Any discrepancies were resolved through consensus between the two researchers.

2.5. Quality appraisal

The JBI critical appraisal checklist for systematic reviews and research syntheses[28,29] was used to assess the quality of included reviews. This tool, applicable to both quantitative and qualitative studies, contains eleven items rated as 'yes', 'no', 'unclear', or 'not applicable'. A scoring guide specific to this umbrella review was developed, with 'yes' scored as 1.0, 'unclear' as 0.5, and 'no' as 0.0. Reviews scoring above 75% were considered high quality, 50–75% moderate, and below 50% low quality. Table S2 in Supplementary File presents details of the appraisal matrix. Two researchers independently conducted the assessments and resolved discrepancies through consensus.

2.6. Data extraction

The data extraction table was developed in an MS Excel file following JBI recommendations for umbrella reviews [28]. It was pilot-tested on five included studies and revised as needed. The table included the following main sections: citation details; review questions; number of databases searched; date range of included studies; characteristics of included studies; quality appraisal; evidence certainty assessment; scope of climate action strategies; effectiveness of strategies; policy recommendations; additional notes. Two researchers independently extracted data, compared results, and resolved discrepancies through discussion. In the case of missing data the corresponding authors of included reviews were contacted with the request to provide relevant data.

2.7. Data synthesis

Data were summarized using both quantitative and qualitative methods. Thematic analysis (both inductive and deductive) was used to summarize and map the identified mitigation and adaptation strategies. To identify the scope of overlapping publications (primary studies) across included systematic reviews the corrected covered area (CCA) was calculated following the Pieper at al. [36] method. The results of the quality appraisal of included systematic reviews, together with extracted data on evidence certainty (where available), were taken into consideration while drawing final conclusions and formulating policy recommendations [37].

3. RESULTS

3.1. Search results

The search across the five scientific databases identified 4,433 records. After removing duplicates, 2,713 records were screened based on titles and abstracts, leading to 191 articles selected for full-text review. Of these, 37 publications met the inclusion criteria. The most common reason for exclusion was an inappropriate study design, usually related to the absence of quality appraisal of included studies in scoping reviews, or an unsuitable publication type – usually narrative reviews, where search results were not summarized (Fig. 1). Table S3 Supplementary File provides the full list of excluded studies along with the reasons for their exclusion. Two additional reviews were identified through reference list screening, resulting in a total of 39 included reviews (37 systematic reviews, one scoping review, and one integrative review—all meeting the criteria for study quality appraisal and reporting) (Table S4 in Supplementary File).

3.2. General overview of the included reviews

Table 3 presents a general overview of the included reviews. All 39 were published within the last five years (2020–2025). The vast majority (35/39) focused on environmental sustainability. Three reviews addressed climate adaptation actions, while one included primary studies examining both mitigation and adaptation strategies at the hospital level (Fig. 2). The number of primary studies included in the reviews ranged from 8 to 205, while the total number of studies across all 39 reviews was 1,161 (933 after eliminating overlapping ones). The majority of reviews (21/39) included relatively new research (published since 2010) and applied language limitation to studies published solely in English (25/39). With the exemption of one [38], all reviews included studies conducted either exclusively (23/39) or predominantly in high-income countries (15/39) (Table 3). The overall corrected covered area (CCA) ratio is 0.64%, (0.77% and 0.28% in the mitigation and adaptation groups, respectively) indicating only slight overlap of primary studies across the included reviews.

*colours: green – environmental sustainability (mitigation); orange – climate resilience (adaptation); grey – both mitigation and adaptation; the box's size corresponds to the number of primary studies included in the reviews (n = 1161 across all 39R)

Table 3
General overview of the included systematic reviews (chronological order)

No	1st author and ref. no	Publication year	Dimension*	Review's topic	No of incl. stud.	Country of origin of incl. stud. (high- vs, middle, vs low-income countries)	The date range of incl. studies	Quality assessment result
1	Carino [39]	2020	M	food waste in hospitals (across supply chain)	80	Mixed, mostly high-income, with the highest no. of studies from: US (19), UK (8), Denmark (8), Australia (5)	1945–2018	high
2	Rizan [40]	2020	M	surgical operations (mix)	8	Mixed, mostly high-income: US (4), UK (2), Chile (1), India (1)	2011–2018	moderate
3	Mashallahi [41]	2022	M, A	mix - hospitals mitigations and adaptation	26	Mixed, mostly high-income, with the highest no. of studies from: US (5), Australia (4), UK (4)	2009–2020	high
4	Mohtady Ali [42]	2022	A	hospital disaster preparedness	22	Mixed, high-, middle and low-income countries. The highest no of studies from: US (4), Australia (3), China (3), UK (2), Sierra Leone (2)	2006–2021	high
5	Papadopoulou [43]	2022	M	surgical operations - minimally invasive surgery	16	Mixed, mostly high-income: US (9), Japan (2) + 1 from Germany, Canada, France, India	2005–2021	moderate
6	Anudjo [44]	2023	M	radiology (mix)	14	High income: US (5), The Netherlands (2), Switzerland	2015–2023	high

*M - mitigation, A - adaptation

No	1st author and ref. no	Publication year	Dimension*	Review's topic	No of incl. stud.	Country of origin of incl. stud. (high- vs, middle, vs low-income countries)	The date range of incl. studies	Quality assessment result
						(2) + 1 from UK, Germany, Ireland, Canada, Australia		
7	Batcup [45]	2023	M	mix - behavioural change interventions (in clinical settings)	20	High income: UK (15), US (3), Australia (2)	2016–2021	high
8	Cook [46]	2023	M	food waste in hospitals	85	Mixed, mostly high-income, with the highest no. of studies from: US (37), Australia (15); Canada (9), UK (9)	2002–2020	high
9	Keil [47]	2023	M	single-use vs reusable healthcare products (mostly within surgical operations)	27	High income with the highest no of studies from: US (11), Australia (5), Germany (2), The Netherlands (2)	2008–2022	moderate
10	Lam [48]	2023	M	surgical operations (mix)	21	High income with the highest no of studies from: US (11), UK (7), Australia (5)	2012–2022	moderate
11	Perry [49]	2023	M	surgical operations (mix)	34	High income with the highest no of studies from: US (18), Australia (6), UK (5)	1994–2018	high
12	Pickard Strange [50]	2023	M	telemedicine	23	High income, with the	1996–2021	high

*M - mitigation, A - adaptation

No	1st author and ref. no	Publication year	Dimension*	Review's topic	No of incl. stud.	Country of origin of incl. stud. (high- vs, middle, vs low-income countries)	The date range of incl. studies	Quality assessment result
						highest no of studies from: UK (8), US (7), Spain (2)		
13	Rodler [51]	2023	M	telemedicine	48	High income with the highest no of studies from: US (20); UK (12); Australia (5); Canada (3)	2013–2023	high
14	Wicklum [52]	2023	M	PHC - decarbonisation toolkits (mix)	20	Mixed, mostly high-income, with the highest no. of studies from: US (8), UK (7), Canada (4)	2007–2022	moderate
15	Blom [38]	2024	M	mix - different strategies / health system levels	22	Middle income, with the highest no of studies from India (6), China (3), Malaysia (2), Pakistan (2)	2000–2022	high
16	Braithwaite 2024 [53]	2024	M	mix - different strategies / health system levels	205	Mixed, mostly high income, with the highest no of studies from: US (27), UK (21), Australia (17), and Canada (14).	2005–2023	high
17	Chauvet [54]	2024	M	surgical operations - single vs multiuse laparoscopic instruments	14	High income: US (4), UK (3) + 1 from Australia, Canada, Belgium, France,	1994–2022	moderate

*M - mitigation, A - adaptation

No	1st author and ref. no	Publication year	Dimension*	Review's topic	No of incl. stud.	Country of origin of incl. stud. (high- vs, middle, vs low-income countries)	The date range of incl. studies	Quality assessment result
						Germany, Greece, Switzerland		
18	Cohen [16]	2024	M	surgical operations – obstetrics and gynaecology (mix)	17	Mixed, mostly high income: US (11), Canada (2), UK (1), Netherlands (1), multi-country (2)	2004–2022	moderate
29	Davies [12]	2024	M	surgical operations (mix)	11	High income: US (8), Canada (2), multi-country (1)	2010–2021	moderate
20	Eussen [55]	2024	M	surgical operations - single vs multiuse instruments	53	Mixed, mostly high-income, with the highest no. of studies from: US (15), Germany (10), UK (7)	1991–2023	moderate
21	Gumera [56]	2024	M	surgical operations - single vs multiuse headwear	9	High income: US (8), the Netherlands (1)	2017–2022	high
22	Kloevekorn [13]	2024	M	surgical operations (mix)	18	High income: US (6), UK (3), Australia (2), Canada (2) + 1 from Turkey, France, Spain, Denmark, Ireland	2018–2024	moderate
23	Martins [57]	2024	M	surgical operations - single vs multiuse instruments in minimally invasive procedures	13	High-income: Denmark (3), US (3), Australia (2) + 1 from France, Ireland, Sweden, UK, Germany	2005–2023	high
24	Nolan [58]	2024	M	surgical operations -	13	High income: UK	2011–2022	high

*M - mitigation, A - adaptation

No	1st author and ref. no	Publication year	Dimension*	Review's topic	No of incl. stud.	Country of origin of incl. stud. (high- vs, middle, vs low-income countries)	The date range of incl. studies	Quality assessment result
				behavioural interventions on anaesthetic agents		(9), US (2) + 1 from Australia, New Zealand		
25	Pickles [59]	2024	M	mix - different strategies / health system levels	21	High income, with the highest no of studies from: US (7), UK (6), Australia (3)	2011–2023	high
26	Roletto [60]	2024	M	radiology (mix)	16	High income: US (7), Switzerland (3), UK (2), + 1 from Ireland, Canada, Australia, Germany	2010–2023	moderate
27	van der Zee [61]	2024	M	telemedicine	28	High income with the highest no of studies from: UK (10); US (10); Australia (2)	2010–2022	moderate
28	Vu [62]	2024	M	surgical operations (mix)	13	High income: US (7), Canada (3), France (2), Portugal (1)	2010–2023	moderate
39	Cunha [63]	2025	M	surgical operations - abdominal surgery	8	High income: US (5), UK (2), Italy (1)	2008–2023	moderate
30	Iakovou [64]	2025	M	surgical operations - plastic surgery	15	High income: US (10), UK (3), Chile (1), Switzerland (1)	2017–2023	high
31	Johar [15]	2025	A	community-based heat adaptation	10	Mixed, mostly high income: Australia (2), Japan (2), China (2) + 1 from	2000–2023	high

*M - mitigation, A - adaptation

No	1st author and ref. no	Publication year	Dimension*	Review's topic	No of incl. stud.	Country of origin of incl. stud. (high- vs, middle, vs low-income countries)	The date range of incl. studies	Quality assessment result
						US, Canada, Italy, Pakistan		
32	Hammer [65]	2025	M	surgical operations - anaesthetic agents	13	High income: France (3), US (4), Germany (2), Switzerland (1), Singapore (1), South Korea (1), Australia (1)	2019–2024	moderate
33	Nunes [66]	2025	M	PHC – decarbonisation (mix)	15	High income: UK (5), Australia (3), US (2), Germany (2) + 1 from France, Switzerland, Israel	2016–2023	high
34	Onasanya [67]	2025	M	pharmaceuticals - inhalers	64	Mixed, mostly high income with the highest no of studies from UK (24)	2014–2024	high
35	Peyrottes [68]	2025	M	surgical operations - single vs multiuse instruments in urological endoscopic procedures	10	High income: Australia (3), France (3) + 1 from Canada, Ireland, UK, US	2018–2024	high
36	Pitard [69]	2025	M	pharmaceutical - hospital pharmacy (mix)	17	Mixed, mostly high-income: France (4), US (4), Ethiopia (2), Saudi Arabia (2) + 1 from England, Italy, Netherlands, Brazil, Spain.	2014–2022	high
37	Tozsin [11]	2025	M	surgical operations -	10	High income:	2018–2024	moderate

*M - mitigation, A - adaptation

No	1st author and ref. no	Publication year	Dimension*	Review's topic	No of incl. stud.	Country of origin of incl. stud. (high- vs, middle, vs low-income countries)	The date range of incl. studies	Quality assessment result
				single vs multiuse instrument in urological procedures		France (3), US (2), Italy (2), Ireland (2), UK (1)		
38	Zurynski [14]	2024	A	health workforce preparedness	60	Mixed, mostly high-income, with the highest no. of studies from: US (29), Australia (6)	2004–2023	high
39	van Nieuwenhuizen [70]	2025	M	surgical operations (mix)	42	High-income, with the highest no. of studies from: US (20), Australia (4), UK (3)	2012–2023	high

*M - mitigation, A - adaptation

3.3. Quality of the evidence base

More than half (23/39) of the included reviews were of high quality, while the remaining reviews were classified as being of moderate quality. Overall, the average quality score was 77%. The three most common quality problems were (1) lack of clearly and explicitly stated review question (28/39); (2) inclusion criteria not based on a dedicated framework (e.g., PICO) (22/39); and (3) searches conducted in fewer than five databases (23/39) (Table S2 in Supplementary File).

In 23 reviews, a single instrument/checklist was used to assess the quality and/or risk of bias of the included primary studies, while in the remaining 16 reviews, between two and four different instruments were used (depending on the type of primary studies). In most reviews, the results of quality appraisal/risk of bias assessment of individual studies varied considerably. In only two reviews [44,60], the pooled, overall quality score was above 80%, while in the vast majority of cases, the results were not pooled, only presented for each individual primary study and ranged from low or moderate to high quality/risk of bias. In two reviews [42,53], studies of low quality were excluded from the data synthesis. In three reviews [38,59,70], the certainty of evidence was assessed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE)[71,72] approach, and in all three cases the overall certainty of evidence was rated as low (Table S5 in Supplementary File).

3.4. Evidence on the scope and effectiveness of environmental sustainability actions

The 36 reviews on mitigation strategies (including one addressing both mitigation and adaptation) focused on eight main themes (see Fig. 2). More than half concentrated on different types of surgical operations (20/36). Other themes included food waste, telemedicine, radiology, pharmaceuticals, primary health care, behavioural interventions, and mixed strategies at different health system levels, each addressed in in two or three reviews.

The identified mitigation strategies can be clustered into five main dimensions based on Braithwaite at al. [53], including: 1) optimizing energy use in buildings and equipment (e.g., switching to renewable energy sources, turning off the equipment when not in use); 2) changing clinical care to reduce environmental impact (e.g., moving away from anaesthetic gases with high global warming potential; choosing medical pathways with lower environmental impact; reducing low-value care, implementing water saving measures); 3) reducing waste and improving its management (e.g., replacing single-use medical instruments and protective materials by multi-use options; waste reduction, reuse and recycling; recovering energy from waste); 4) reducing travel and transport (e.g., telemedicine, scheduling consultation to minimize patient travel, remote professional cooperation); and 5) reducing supply chain emissions (e.g., through local and green procurement) (Table 4).

Table 4
Reviews' themes and mitigation actions dimension matrix

Review's theme / Mitigation dimension	Optimizing energy use in buildings & equipment	Changing clinical care to reduce impact on environment	Reducing waste and improving its management	Reducing travel and transport	Reducing supply chain emissions
Surgical operations: 20R, n = 365	✓	✓	✓		
Food waste: 2R, n = 165			✓	✓	✓
Telemedicine: 3R, n = 99				✓	
Radiology: 2R, n = 30	✓	✓	✓	✓	
Pharmaceuticals: 2R, n = 81		✓	✓		✓
PHC: 2R, n = 35	✓	✓	✓	✓	✓
Behavioural interventions: 1R, n = 20		✓	✓		
Mix - different strat. /system levels: 4R, n = 274	✓	✓	✓	✓	✓

Table 5 presents a general overview of the identified mitigation strategies (as classified in reviews) and the available evidence on their effectiveness. For the vast majority of identified strategies, the results clearly indicated a positive impact on the environment, manifested as reduced GHG emissions and/or reduced waste or water use. However, for two types of actions: 1) replacing single-use medical instruments (used mostly in surgical procedures) by reusable alternatives, and 2) selecting a surgical technique with lower emissions (mostly robot-assisted versus laparoscopic) – the evidence was mixed. While most high quality studies reported significant environmental advantages of reusable surgical instruments [40,48,57], some studies suggested the opposite [11] or found no differences in carbon footprint between single and multiuse instruments [68]. Similarly, some studies indicated lower GHG emissions from robot-assisted surgeries compared to laparoscopic ones [11,63], while others reported the opposite result [16,63].

Table 5
Synthesis of the identified mitigation actions and their effectiveness (36R)

Review's theme	Strategy/Action	Evidence on effectiveness*	Impact on environment
Surgical operations: 20R, n = 365	moving away from anaesthetic gases with high global warming potential (GWP)	✓ reduction of volatile anaesthetics, especially desflurane, lead to decrease in CO2e emissions between a 24% and a 98% [65] ✓ 12 out of 13 included studies reported reduced CO2e after application of educational interventions e.g., encouraging lowering fresh gas flow, applying intravenous anaesthesia [58] ✓ use of sevoflurane or propofol resulted in up to 60% reduced GHG emissions versus desflurane use [43] ✓ converting all suitable procedures from general to spinal anaesthesia can generate substantial CO2e savins [48]	positive
	optimizing energy use in operating theatres (OR)	✓ turning off airflow systems during nights and weekends can save up to 70% of total energy use [70] ✓ installing occupancy sensors, low-energy lighting, energy efficient air-conditioning systems and water cooling systems showed significantly reduced carbon emission [40] ✓ turning off idle sterilizers reduced electricity by 26% and water use by 13% [49] ✓ installing occupancy sensors in the OR let do decreased CO2 emissions by 234.2 tons [48]	positive
	replacing single-use medical instruments with multi-use options	✓ using reusable items showed a 70% waste reduction, 3 times lower water use, and 2.5 times lower energy consumption than disposables; disposable steel scissors had 99% higher environmental impact than reusable ones [40] ✓ hybrid devices in laparoscopic cholecystectomy emitted less CO2e than single-use devices (1.8 vs. 7.2kg) [63] ✓ 7 out of 8 studies showed lower environmental impact when using reusable endoscopic instruments [55] ✓ 3 high quality life cycle assessment studies (LCA) showed that multiuse instruments have a significantly lower (2–26 times) environmental footprint than their single-use counterparts in minimally invasive surgeries; several fair/poor quality studies favoured single-use [57] ✓ reusable equipment reduced CO2 emissions by 40–66% compared to single-use equivalents [48] ✓ single-use cystoscopes had lower emissions per procedure (2.4 kg) compared to their	mixed

*if available, quantitative data are presented; otherwise a descriptive information is used

Review's theme	Strategy/Action	Evidence on effectiveness*	Impact on environment
		reusable counterparts (4.2 kg) but produced more waste; reusable cystoscopes, while having a lower cumulative waste per use, increased emissions due to energy-intensive reprocessing (the cumulative emissions results may depend on the sterilisation techniques and must be analysed by LCA) [11] ✓ in ureteroscopy, studies tend to show comparable carbon footprints for single-use and reusable instruments [68] ✓ minimal material and maximum reuse of equipment during hysterectomy resulted in 69% GHG emission reduction [43]	
	minimising waste produced by instruments packaging	✓ repackaging of disposable instruments into packs of essential items customized to laparoscopic gynaecological surgery at their institution, resulting in waste reduction of 400 g per case [43] ✓ using 'green packs' for 'wide awake local anaesthesia no tourniquet' cases showed a significant waste reduction (2.3 kg per case)[64] ✓ redesigning of hand surgery packs led to a 2.8 tonnes waste decrease [64]	positive
	replacing single-use medical protective materials (e.g., headwear) by multi-use options	✓ reusable surgical head covers demonstrated a statistically significant lower carbon footprint, ozone depletion, fossil fuel depletion, terrestrial acidification, and fine particulate matter formation than disposable alternatives, while not impacting the surgical site infection rates [56]	positive
	changing surgical techniques to those with lower environmental impact	✓ robot-assisted surgery had a higher environmental impact than laparoscopic and open surgery [70] ✓ 2 studies on hysterectomy showed that robotic surgery had the highest emissions (12.0–40.3 kg CO_2e) compared to laparoscopic (10.7–29.2 kgCO_2e) and open surgery (7.1–22.7 kgCO_2e); 1 study showed that laparoscopic prostatectomy produced more emissions than robotic option (59.7 vs. 47.3 kgCO_2e) due to higher disposable devices, longer surgery time and length of stay [63] ✓ robotic prostatectomy produced lower emissions than laparoscopic methods [11] ✓ using alcohol-based scrub limits water use (18.5 litres per person per scrub) [49] ✓ increasing the lifetime of multi-use devices and fully loading autoclaves for their sterilization further decrease their environmental impact [47] ✓ reducing custom pack contents and replacing single-use items reduced caesarean procedure	mixed

*if available, quantitative data are presented; otherwise a descriptive information is used

Review's theme	Strategy/Action	Evidence on effectiveness*	Impact on environment
		footprint by 22% [16]	
	improving waste management	✓ increasing recycling resulted in a 2% reduction in greenhouse gas emissions [48] ✓ waste segregation/recycling and minimising unused supplies reduced emissions [13] ✓ installing paper and cardboard recycling bins in anaesthetic room and operating theatre increased recycling (up to 50%-67% waste) [49] ✓ educational campaign reduced infectious medical waste by 75% [48]	positive
Food waste: 2R, n = 165	choosing local suppliers/procurement	✓ using local food (direct 'farm to hospital' procurement), which limits transport, is most environmentally beneficial [39]	positive
	using food ingredients and preparation techniques with lower environmental impact	✓ mediterranean-style diets and vegetarian menu generated lower GHG emissions and water use than the standard menu [39] ✓ using lean process tools reduced pre-service waste by 50%; fortified small portions decreases food waste by 5% [39]	positive
	adopting consumption methods that minimize waste	✓ using bulk trolley instead of plating food in the kitchen; enabling patient choice (e.g., room-service model) and using porcelain plates instead of plastic trays reduced food waste by 8% [39]	positive
	improving food waste management	✓ composting waste and donating surplus food substantially decreased total food waste volume [39,46] ✓ most strategies that avoid and/or reduce sending food waste to landfill (e.g., industrial use, feeding animals, worm farms) helped to limit GHG emissions	positive
Telemedicine: 3R, n = 99	implementing remote (telephone and video) consultations	✓ all studies across all three reviews showed that telemedicine reduces GHG emissions due to limited travel (though not all included primary studies calculated telemedicine emissions) [50,51,61] ✓ although limited, the studies where complete LCA of telemedicine solutions was performed also showed GHG emission reduction due to replacing face-to-face visit with remote options [51]	positive
Radiology: 2R, n = 30	optimizing energy use	✓ turning off workstations/devices after hours saved a substantial part of total energy [44,60] ✓ choosing energy efficient radiological equipment [44]	positive
	reducing the use of consumables and	✓ limiting the use of diatrizoic acid (contrast agent) reduced environmental contaminations	positive

*if available, quantitative data are presented; otherwise a descriptive information is used

Review's theme	Strategy/Action	Evidence on effectiveness*	Impact on environment
	radiopharmaceuticals	(e.g. in rivers) [44]	
	reducing patients' and staff travel	✓ investing in teleradiology/remote collaboration - online conferences (e.g., switching to online, the annual Radiological Society of North America conference can save 40 000 tons of CO2e due to travel) [44]	positive
Pharmaceuticals: 2R, n = 81	reducing pharmaceutical waste	✓ diversity of actions described as effective, including e.g.: educational interventions (for both patients and staff); providing information (audit and feedback on waste values; monthly bulletins of waste production); reminders to return unused medicines; changing dispensing/distribution practice (dosage on demand; increased frequency of batches preparation), incorporating of environmental sustainability rules into procurement contracts [67,69]	positive
	switching to pharmaceuticals with lower carbon footprint	✓ switching inhalers from metered-dose (MDI) to dry powder inhalers (DPI) significantly lowered the carbon footprint while at the same time improved asthma control and adherence [67]	positive
PHC: 2R, n = 35	delivering PHC's decarbonisation toolkits	✓ 11 toolkits were identified, all including educational materials for PHC staff, while 7 also included resources for patients; majority focused on clinical operations, procurement, energy use, and waste and recycling – although quantitative data were limited, the available evidence pointed towards a reduced environmental impact after toolkits implementation [73]	positive
	implementing mix of actions, incl.: reuse of resources, improving waste management, revising prescriptions; saving energy; promoting telemedicine and health education	✓ no quantitative data were provided and the identified strategies' results were not consistently reported; some strategies proved effective in reducing emissions (e.g., energy efficient solution; limiting patient travel by telemedicine and changes in appointment scheduling and prescription collection; social prescribing reduced further health care use, switching to dry powder inhalers reduced emissions) [74]	positive
Behavioural interventions: 1R, n = 20	implementing a mix of behaviour change techniques, incl.: change in policy/protocols, email updates, announcements, presentations, personalised and team feedback, reminder notes	✓ some strategies, especially comprehensive ones that applied more than one behavioural technique proved effective in reducing emissions, with most evidence focused on interventions that targeted anaesthesia and pathology test ordering in hospital settings, e.g., educational intervention on anaesthetic gases flow rate in perioperative settings showed 105 kg of CO2e reduction per case; behavioural intervention to reduce biochemical test ordering showed 10 tons of CO2e reduction per year [45]	positive
Mix - different strategies / health system levels: 4R, n = 274	changing clinical and surgical care pathways to reduce environmental impact	✓ interventions related to changing anaesthesia agent practices can lead to GHG reduction between 25% – 100% [59] ✓ targeting unnecessary resting (low-value care) limited emissions by 10%-37% [59]	positive
*if available, quantitative data are presented; otherwise a descriptive information is used			

Review's theme	Strategy/Action	Evidence on effectiveness*	Impact on environment
		✓ implementing multicomponent interventions to reduce low-value care (incl.: identifying and reducing unnecessary processes or procedures, minimising drug overprescription, encouraging a preventative care approach to reduce the need for health services) can successfully reduce emissions [53] ✓ implementing water use saving plans (e.g., automatic shut-off / low pressure valves, reporting water use to staff) can reduce water consumption [41]	
	reducing waste volume and improving waste managements	✓ multicomponent waste reduction intervention incl. clinician education, audit and feedback, recycling, relocation of landfill, and converting from single-use to reusable sharps containers led to reducing GHG emission by 32%-85% [59] ✓ systems integrating waste segregation, composting and material recycling with simultaneous transport optimisation generated greatest emission reductions, ranging from 47%–114% [38]	positive
	reducing travel and transport	✓ numerous studies examining different approaches to reduce travel and transportation (telemedicine, local care options, shared transport options, scheduling face-to-face appointment to minimize travel needs, reducing health professional's business trips) showed positive results in terms on GHG emission reductions [53]	positive
	optimizing energy use (in buildings and equipment)	✓ using a mixed energy sources or fully renewable once, led to CO2 emission reductions of 25%–233% [38] ✓ conserving energy by optimizing equipment use (switching off when not used, sleep-mode) can reduce emissions[53] ✓ investing in infrastructural solutions that maximise use on natural light (windows exposure) and minimizes the need for air-conditioning (insulation, reflective materials) [41]	positive
	decarbonising the supply chain	✓ numerous studies showed that green procurement (e.g., using sustainable or local sources of food supply, or using supply chains with low emissions) can reduce emissions [53]	positive

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All 36 reviews on mitigation strategies focused on environmental impact (mostly GHG emissions) usually as a primary outcome measure, while 15 of them also included financial costs and/or quality of care as additional outcomes of interest. Among these, five reviews evaluated all three aspects simultaneously: impact on environment, costs and quality of care (Table 6). The majority of the existing evidence indicated that mitigation actions have a positive impact on environment (reduced emissions, waste) and costs (costs savings), as well as a positive or neutral impact on quality of care (e.g., mortality, surgical site infection, asthma control).

Table 6
Results of the reviews on mitigation, with multiple outcome measures (15R)

1st author and ref. no	Review's topic	Mitigation action's impact on		
		Environment	Costs	Quality of care
Batcup [45]	mix - behavioural change interventions	positive	positive	n/a
Blom [38]	mix - different strategies / health system levels	positive	mostly positive	mostly positive
Carino [39]	food waste (across hospital supply chain)	positive	positive	n/a
Chauvet [54]	surgical operations - single vs multiuse laparoscopic instruments	positive	positive	mixed
Eussen [55]	surgical operations - single vs multiuse instruments	positive	positive	neutral
Gumera [56]	surgical operations - single vs multiuse headwear	positive	positive/ neutral	neutral
Iakovou [64]	surgical operations - plastic surgery	positive	positive	n/a
Onasanya [67]	pharmaceuticals - inhalers	positive	n/a	positive
Papadopoulou [43]	surgical operations - minimally invasive surgery (robotic vs laparoscopic)	mixed	positive	n/a
Pickard Strange [50]	telemedicine	positive	positive	n/a
Pickles [59]	mix - different strategies / health system levels	mostly positive	mostly positive	neutral
Pitard [69]	pharmaceuticals - hospital pharmacy (mix)	positive	mostly positive	n/a
Rodler [51]	telemedicine	positive	positive	n/a
Roletto [60]	radiology (mix)	positive	positive	n/a
Vu [62]	surgical operations (mix)	positive	positive	n/a

Note: a positive outcome on costs implies lower costs for healthcare providers.

3.5. Evidence on the scope and effectiveness of climate resilience actions

Among the four reviews on climate resilience (including one addressing both mitigation and adaptation actions) two focused on hospital disaster preparedness [41,42], one on health workforce[14] and one on community heat adaptations actions [15]. Only the latter reported direct outcome measures (Table 7). Consequently, the evidence on the effectiveness of particular actions is largely descriptive. Multicomponent educational activities, targeting both health professionals and patients, were the most often reported form of adaptation strategy.

Table 7
Synthesis of the identified adaptation actions (4R)

Review's theme	Strategy/Action
Hospital disaster preparedness: 2R, n = 48	✓ continuous education of health care professionals on disaster preparedness, including multi-professional, scenario-based educational trainings [42] ✓ availability of disaster response protocols (including additional supplies availability patterns) developed and updated by the dedicated emergency preparedness committee [42] ✓ early warnings/ outbreaks detection IT systems [42] ✓ investing in climate-proof infrastructure solutions (e.g., insulation, reflective materials to reduce receiving heat inside buildings; architectural design to reduce risk of flooding, or damages due to strong winds) [41]
Workforce preparedness: 1R, n = 60	✓ disaster preparedness training (incl. actionable protocols, drills, evacuation plans and interprofessional collaboration) [14] ✓ planning for staff surge capacity (scheduling and contingency plans, effective mobilisation strategies, role flexibility and adequate incentives structure) [14] ✓ psychological support (counselling during and after climate events) [14]
Community heat adaptations: 1R, n = 10	✓ multicomponent educational interventions delivered in community settings (e.g., written and digital media, individual communication) can be effective in improving heat literacy, behavioural adaptation, and health outcomes (incl. reduced number of hospital visits, reduced heat related health events) [15]

4. DISCUSSION

To the best of our knowledge, this is the first umbrella review synthesizing systematic reviews on health system responses to climate change. Four main findings emerge. First, there is a large and rapidly growing evidence base: we identified 39 reviews published between 2020 and 2025, covering more than 900 primary studies, mostly originating from high-income countries. Second, the literature is strongly concentrated on mitigation strategies, while evidence on adaptation and climate resilience remains comparatively scarce. Most research focuses on actions implemented at the level of individual healthcare providers or clinical practices, with more than half addressing mitigation actions in surgical care, whereas other themes – including food waste, telemedicine and transport, radiology, pharmaceuticals, primary health care, behavioural interventions, and mixed strategies across health system levels – are each covered by only a small number of reviews. Third, the available evidence indicates that many mitigation actions generate environmental and economic co-benefits by simultaneously reducing emissions and costs, although much of the underlying research is of low to moderate quality. Emerging evidence further suggests that mitigation interventions have no – or maybe even a positive – impact on quality of care. Finally, several findings – particularly regarding reusable instruments and specific surgical techniques – appear to be highly context dependent.

Our findings are in line with results of previous evidence syntheses focusing on climate mitigation strategies within health systems, e.g., Braithwaite et al. [53] and Seppänen & Or [19]. However, our work covers a broader literature base, reports on quality appraisal of both the systematic reviews and the underlying primary studies, provides more details on the effectiveness of particular strategies, and draws attention to (potential) co-benefits of interventions for environmental sustainability and costs. It provides the most comprehensive overview of the available literature to date.

However, before discussing the implications for policy and research, several limitations should be noted. First, the evidence base shows substantial methodological heterogeneity. Across the included reviews, effectiveness data were reported in different formats (quantitative versus descriptive) and at different levels of aggregation (individual studies, pooled results, or fragmented summaries). Reviews also applied a wide range of quality appraisal and risk-of-bias tools – more than 30 different tools were used, up to four in a single review (Table S5 in Supplementary File). This limited comparability and prevented a quantitative synthesis or overall grading of evidence certainty. Second, many underlying primary studies were assessed as

having low to moderate methodological quality, which reduces reliability of the results. Third, our inclusion criteria focused on reviews primarily addressing health system actions, while climate resilience often depends on intersectoral measures involving urban planning, transport, agriculture and food systems, energy, and housing.[7,75]; relevant evidence from these areas may therefore not be fully captured. Finally, only a subset of reviews included life-cycle assessment (LCA) studies, which are considered the gold standard for evaluating environmental impacts [76,77]; summary statistics of the available evidence could not be calculated as not all reviews reported methodological details about the included studies. These limitations highlight the need for more standardized methodologies and reporting practices in future research.

Nevertheless, our findings have important implications for policymakers and researchers. First, the large body of available evidence provides practical guidance for reducing the environmental footprint of healthcare in several well-identified emission hotspots, including surgical care, radiology, pharmaceuticals, patient and staff transport, and food waste:

- Surgery is highly resource-intensive: it uses three to six times more energy than other hospital wards [78], accounts for 30% to 50% of hospital waste, including mostly single-use plastic products and packaging [49,79], and represents up to 60% of total hospital emissions [80]. Reducing the use of high-emission anaesthetic gases, improving operating room energy management, optimising surgical pathways, and increasing the use of reusable instruments can make a substantial contribution to environmental sustainability [49,79 81].
- Pharmaceuticals account for about 25% of health system emissions [82,83], with certain medicines having a disproportionate impact. For example, inhalers generate about 3% of total NHS emissions in England. Key mitigation approaches include reducing pharmaceutical waste and selecting medicines with lower environmental impact, such as switching from metered-dose to dry-powder inhalers where clinically appropriate.
- Clinical radiology and radiotherapy contribute about 10% of the healthcare carbon footprint [44]. The major drivers are energy-intensive equipment, large data storage needs, and waste from consumables, including radiological contrast agents [84,85]. Existing evidence suggests that 40% to 91% of energy use occurs during idle time, when devices are switched on but not operating [60]. In addition, there is growing evidence on low-value diagnostic imaging – including, for example, MRI and CT scans which are unnecessarily performed [86], thus the potential for emission reduction is substantial.
- Food waste represents approximately 20% to 30% of total hospital waste, with plate waste averaging around 30%-40% [87], but varying depending on the type of ward. When decomposed in landfills, food waste emits methane which has a global warming potential 28 times greater than carbon dioxide [88]. Mitigation actions for food waste in hospitals cover all areas of the general food recovery hierarchy[89], with prevention of waste generation as the most effective approach.
- Transport and travel account for 14% to 22% of healthcare emissions [83,90]. Much of the existing mitigation evidence in this area focuses on telemedicine as an effective way to limit both patients and health professional transport.

To achieve system-wide impact, these insights need to be translated into formal policy instruments such as clinical guidelines, procurement standards, and organisational sustainability strategies. Some examples already exist, *The Green Surgery Report* [91] by the UK Health Alliance on Climate Change, *The Greening the Operating Room and Perioperative Arena guidelines* [92] by the American Society of Anaesthesiologists, and *Intensive Care Environmental Sustainability Recipe Book* [93] by the Intensive Care Society.

Second, the strong concentration of the literature on mitigation underlines the need for greater attention to climate adaptation in health systems. Climate change is already affecting health systems through heatwaves [94], extreme weather events [95], and changing disease patterns[96], yet only a small number of systematic reviews addressed adaptation or resilience actions. While effective health system adaptation often requires coordination with other sectors—including urban planning, energy systems, and food systems [7] —the limited number of rigorous systematic reviews that assess the quality or certainty of the underlying evidence on heat adaptation, climate-resilient infrastructure, or green resilience approaches within healthcare is notable. Strengthening the evidence base in this area is therefore an important priority for both research and policy.

Third, the evidence on environmental and economic co-benefits provides an important argument for policy action. Many mitigation strategies appear capable of simultaneously reducing greenhouse gas emissions and healthcare costs. In addition, emerging evidence – currently based on just a few reviews[55,56,59] – suggests that investigated mitigation actions have a neutral or maybe even positive impact on quality of care. For example, reviews by Eussen et al.[55] and Gumera et al.[56] showed that reusable medical instruments and reprocessed single use instruments (e.g., scissors, trocars, forceps, Veress needles) as well as reusable surgical headwear, offer significant environmental advantages and lower costs, while maintaining comparable performance and safety to disposable alternatives. Similarly, the review by Onasanya et al.[67] showed that switching to inhalers with much lower emissions was associated with improved inhaler adherence and asthma control. Consequently, policies that prioritise mitigation interventions may align climate objectives with broader health system goals, including cost containment and value-based care. Further research could usefully explore these co-benefits more systematically and examine the environmental implications of other cost-saving care strategies, such as shifting care to ambulatory settings and reducing low-value interventions. Existing efforts to incorporate environmental sustainability criteria (e.g. carbon emissions) in clinical trials [97,98], or health technology assessments[99,100] and prioritising services that can provide the same health effect with lower environmental impact[101] are pointing in the right direction.

Fourth, the environmental performance of specific interventions may vary considerably depending on local conditions such as energy sources, sterilization practices, reuse rates, or the organization of clinical pathways. For example, the relative environmental advantage of reusable vs. single-use medical instruments depends on a range of factors [40,47,57], including the efficiency of sterilisation techniques (e.g., related to packing of autoclaves), the number of reuse cycles, and the proportion of renewable sources in the energy mix. Consequently, a similar mitigation action can be effective in one context and not in another. For example, the carbon footprint of reusable surgical instruments may be much higher in Australian settings (with mostly coal-based electricity) than in European ones (with a higher share of renewable energy sources) [40]. These findings suggest that policy guidance should combine general principles with context-specific assessments. Health systems may therefore benefit from integrating environmental impact evaluations into local decision-making processes, procurement strategies, and clinical pathway redesign.

Fifth, our findings highlight the need to strengthen methodological standards and implementation capacity. The heterogeneity of environmental impact assessment methods across studies limits the comparability and synthesis of results. Wider use of standardized approaches – particularly LCAs – would improve the robustness of the evidence base. LCAs are based on dedicated ISO standards (ISO 14040–14044) [76,77] and allow for a comprehensive product assessment, from ‘cradle to grave’ (material extraction, production, use, and waste management). Furthermore, incorporating environmental impact indicators into standard health information and reporting systems would enable more systematic assessment of the environmental performance of healthcare activities, moving beyond the current reliance on ad hoc analyses conducted for individual studies.

Finally, translating evidence into practice will require stronger integration of climate and sustainability topics into health professional education, clinical training, and continuing professional development programs. We found two reviews underlining the crucial role of educational activities, training and skill development for climate mitigation and adaptation efforts [14,45]. However, current training programs often do not cover climate action topics [102–104]. For example, in 2020 climate change topics were taught in only 15% of medical schools worldwide (survey by The International Federation of Medical Students Associations) [102] ; and surveys among intensive care professionals indicate that many lack formal training on environmentally sustainable practices [105]. Strengthening education and training in this area is therefore an important step toward enabling health professionals to incorporate environmentally sustainable practices into routine decision-making. At the same time, growing engagement among medical students and health professionals suggests increasing interest in this topic, providing a promising foundation for integrating climate and sustainability competencies into future health workforce training [106,107].

5. CONCLUSIONS

This is the first umbrella review synthesizing systematic reviews on health system responses to climate change. It shows that a substantial and rapidly growing body of research exists on health system responses to climate change. The literature is strongly concentrated on mitigation strategies implemented at the level of individual providers – particularly in surgical care – while evidence on adaptation and climate resilience remains comparatively scarce. Across several areas, mitigation actions appear capable of generating environmental and economic co-benefits by simultaneously reducing greenhouse gas emissions and healthcare costs – and some evidence suggests that these benefits can be achieved without compromising quality of care. At the same time, some findings—such as those related to reusable instruments or specific surgical techniques—are highly context dependent.

These findings have important implications for policymakers and researchers: First, the existing evidence base provides practical guidance for reducing environmental impacts in key emission hotspots, including surgical care, radiology, pharmaceuticals, transport, and food waste, which can be incorporated into clinical guidelines, procurement standards, and organisational strategies. Second, the strong focus on mitigation highlights the need to strengthen the evidence base on climate adaptation and health system resilience. Third, the potential for environmental and economic co-benefits provides a strong rationale for policy action. Fourth, the context dependence of several interventions suggests that general policy guidance should be complemented by local environmental impact assessments. Finally, strengthening methodological standards (particularly LCA), more routine collection of environmental data, and incorporation of climate topics in health workforce training could support more systematic and evidence-informed climate action in health systems.

Declarations

Competing interest

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Figures

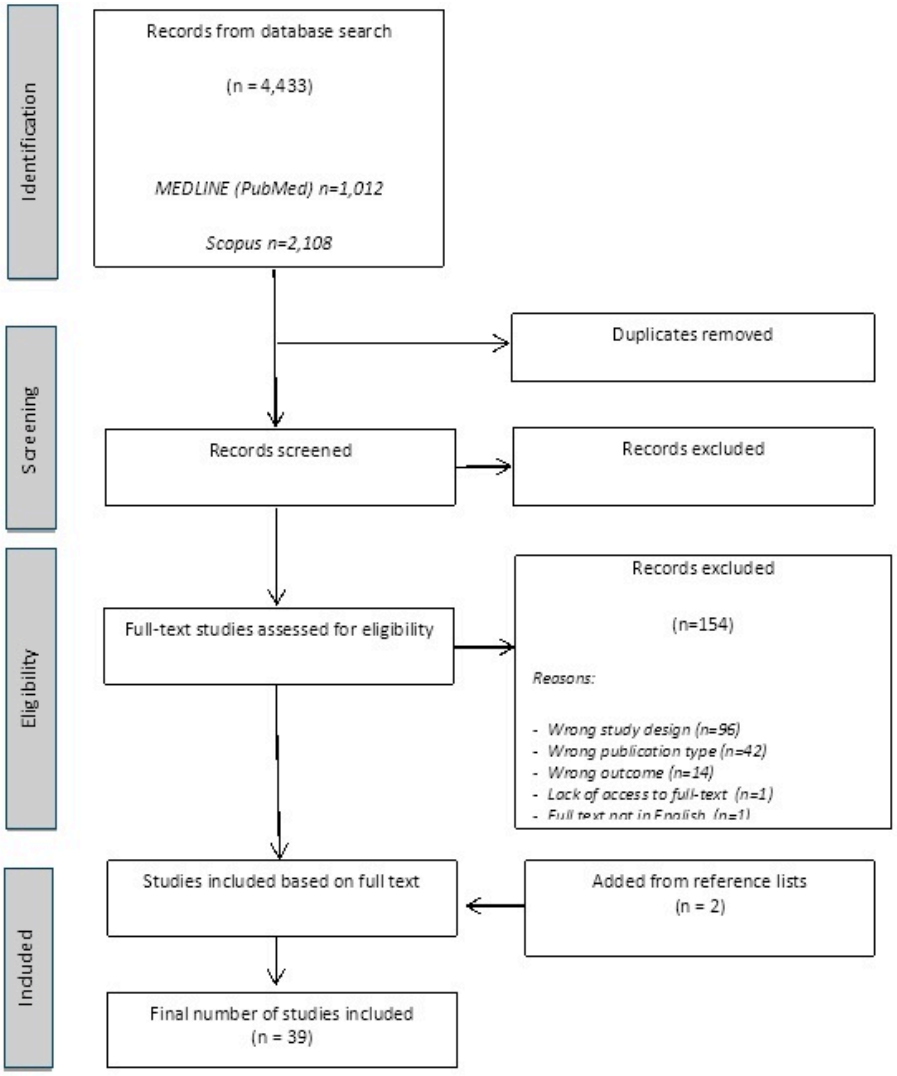


Figure 1

PRISMA flow diagram, summarizing the search results and study selection process

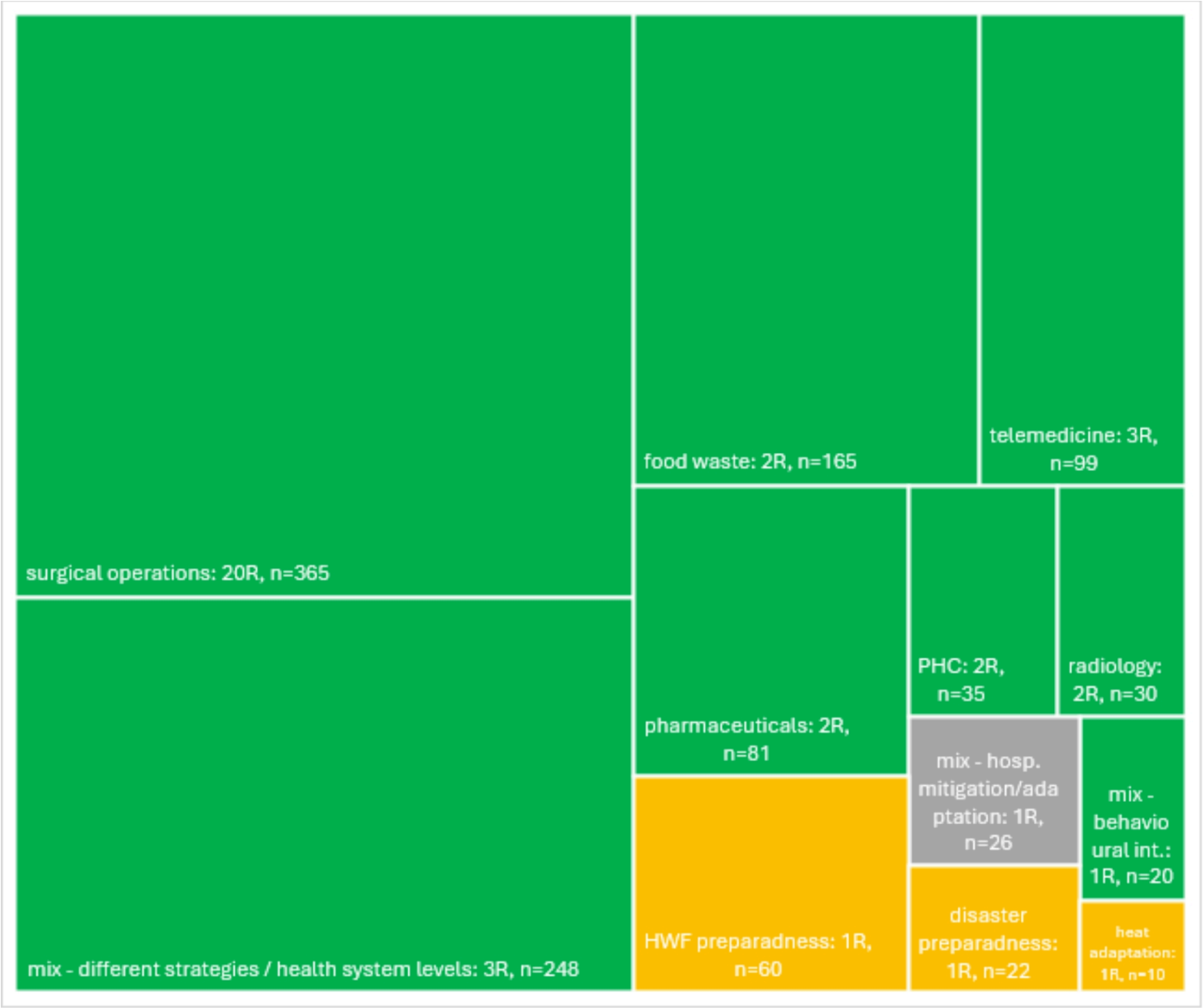


Figure 2

The thematic scope of the included reviews (R)*

*colours: green – environmental sustainability (mitigation); orange – climate resilience (adaptation); grey – both mitigation and adaptation; the box's size corresponds to the number of primary studies included in the reviews (n=1161 across all 39R)