E-ISSN:
Global Public Health & Health Systems Journal Vol. 1, No. 1, May 2026 · Article ID:0005

Article Type: Review DOI:

Health System Adaptation to Climate Change: A Scoping Review of Strategies, Barriers, and Policy Responses

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Received [10 February 2026] **Accepted** [19 May 2026]

Abstract

Background: Climate change is disrupting health systems through extreme heat, floods, storms, drought, shifting infectious disease patterns, infrastructure damage, and widening inequities. Although climate-resilient health systems are prominent in health policy, evidence on actual adaptation strategies, implementation barriers, governance responses, and evaluation gaps remains fragmented.

Objectives: This scoping review mapped evidence on health system adaptation to climate change, focusing on adaptation strategies, barriers and enablers, policy and governance responses, equity considerations, and research gaps.

Methods: A PRISMA-ScR-informed scoping review was conducted. SciSpace, Google Scholar, PubMed, and arXiv were searched from inception to April 2026 using structured terms related to climate change, health systems, adaptation, resilience, governance, financing, workforce, infrastructure, surveillance, and service delivery. Supplementary targeted searches were also conducted. From 831 records identified, 350 unique records were screened, 60 full-text sources were assessed, and 14 key sources were included. Data were charted using a structured template aligned with the six WHO health system building blocks and synthesized narratively.

Results: Adaptation strategies were identified across leadership and governance, health financing, workforce, medical products and infrastructure, health information systems, and service delivery. Reported strategies included mainstreaming climate into health plans, multisector coordination, climate finance reform, workforce training, facility retrofitting, water and energy resilience, early warning systems, climate-health surveillance, continuity-of-care planning, and disaster preparedness. Major barriers were inadequate financing, weak workforce preparedness, fragmented data systems, limited infrastructure investment, policy mimicry, and poor implementation evidence. Equity concerns were prominent but rarely measured.

Conclusion: The literature shows a growing policy architecture for climate-resilient health systems, but implementation and evaluation remain weak. Stronger climate finance, implementation science, surveillance, workforce preparation, and equity-focused governance are urgently needed.

Keywords: climate change; health system adaptation; climate resilience; health system building blocks; health policy; governance

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Peer review under responsibility of Global Public Health, and Health Systems Journal.

A Publication of EcoScribe Publishers company Limited, Uganda.

1. Introduction

Climate change represents a defining challenge for health systems in the twenty-first century. Through a combination of direct and indirect pathways — including extreme heat events, intensifying storms and floods, shifting patterns of vector-borne and waterborne disease, drought-induced food insecurity, and sea-level rise threatening coastal health infrastructure — climate change disrupts every dimension of health system function. The World Health Organization (WHO) has estimated that climate change is expected to cause approximately 250,000 additional deaths per year between 2030 and 2050 from malnutrition, malaria, diarrhoea, and heat stress alone, with the burden falling disproportionately on low- and middle-income countries (LMICs) and vulnerable populations least responsible for greenhouse gas emissions [1].

The concept of a climate-resilient health system — one that is capable of anticipating, responding to, coping with, recovering from, and adapting to climate-related shocks and stresses while maintaining core functions and protecting population health — has gained significant traction in global health policy since the publication of the WHO Operational Framework for Building Climate Resilient Health Systems in 2015 [4]. This framework organizes health system adaptation around the six established WHO building blocks: leadership and governance, health financing, health workforce, medical products and technologies, health information systems, and service delivery. It provides a conceptual architecture that has been widely adopted in country assessments, toolkits, and planning documents, though its practical application and the evidence for its effectiveness remain uneven [4].

Despite the policy momentum, the evidence base on how health systems are actually adapting to climate change remains fragmented. The literature spans a wide range of study types — from facility-level case studies and national adaptation plans to regional scoping reviews and implementation science frameworks — and is geographically uneven, with significant gaps in high-burden regions such as sub-Saharan Africa [1]. Barriers to adaptation are well described in qualitative and policy literature but rarely quantified, and rigorous evaluations of the effectiveness of specific adaptation interventions on health outcomes or system performance are scarce [5]. Financing mechanisms for health sector adaptation are frequently identified as inadequate, misaligned, or inaccessible, particularly for frontline facilities in LMICs [5].

This scoping review was conducted to systematically map the literature on health system adaptation to climate change, addressing four specific objectives: (1) to identify the main health system adaptation strategies described in the literature; (2) to map reported barriers, enabling factors, and implementation challenges; (3) to examine policy and governance responses related to climate-resilient health systems; and (4) to identify major research and practice gaps. By organizing findings according to the WHO building blocks framework and synthesizing evidence across geographic and methodological contexts, this review aims to provide a comprehensive, policy-relevant resource for health system planners, public health practitioners, and researchers working at the intersection of climate change and health systems.

The review is intended to contribute to the evidence base for the journal Global Public Health & Health Systems Journal, which serves researchers, practitioners, and policymakers engaged in health systems strengthening, global health policy, and public health practice. The findings are directly relevant to ongoing international efforts to build climate-resilient health systems, including the Paris Agreement's health commitments, the Sendai Framework for Disaster Risk Reduction, the Sustainable Development Goals, and WHO's global health and climate change agenda.

2. Methods

2.1 Scoping Review Design and Framework

This review was conducted as a scoping review following the PRISMA Extension for Scoping Reviews (PRISMA-ScR) framework. Scoping reviews are appropriate when the aim is to map the extent, range, and nature of evidence on a topic, identify gaps, and synthesize findings across heterogeneous study designs, all of which characterize the literature on health system adaptation to climate change. Consistent with scoping review methodology, formal risk-of-bias appraisal was not used to exclude sources.

2.2 Search Strategy and Information Sources

A systematic search was conducted across four electronic databases: SciSpace, Google Scholar, PubMed, and ArXiv. The search was conducted in January 2026 and covered publications from database inception to the search date. Three structured query variations were used per database to maximize coverage, combining terms for health systems, climate change, adaptation, resilience, governance, policy, and implementation. Search terms included: "health system adaptation climate change," "climate resilient health system," "health system climate governance," "health service preparedness climate change," "climate change health policy," "climate-proofing health facilities," "health workforce climate adaptation," "early warning systems health climate," "national adaptation plan health," and related variants. A supplementary targeted search was subsequently conducted in SciSpace and PubMed to capture additional literature on the WHO Operational Framework, facility-level interventions, health financing for climate resilience, and surveillance systems.

The initial search yielded 751 records across the four primary databases. After deduplication and relevance reranking, 270 unique records were identified. Supplementary targeted searches yielded an additional 80 unique records, producing a final screening pool of 350 unique records. These records underwent title and abstract screening, followed by full-text eligibility assessment for records that appeared potentially relevant.

2.3 Eligibility Criteria

Inclusion criteria: - Peer-reviewed English-language literature, including original empirical studies, policy analyses, framework papers, applied reviews, and case studies - Focus on health system adaptation, climate resilience, health service preparedness, or climate-related policy or governance - Clearly related to health systems responding to or preparing for climate change impacts - Reporting on strategies, barriers, enabling factors, implementation challenges, governance responses, or equity considerations - Relevant to health systems strengthening, service delivery, workforce, infrastructure, financing, or surveillance in a climate context

Exclusion criteria: - Editorials, commentaries, letters, or opinion pieces without empirical or analytical content - Conference abstracts without full results - Studies focused solely on clinical treatment of climate-related illness with no health system component - Papers unrelated to climate change adaptation or health system response - non-English language studies

2.4 Screening and Selection

Title and abstract screening were performed using predefined inclusion and exclusion criteria. The 350 unique records were screened, and 290 records were excluded because they did not meet the eligibility criteria. Sixty full-text sources were assessed for eligibility. Forty-six full-text sources were excluded: not focused on health-system adaptation (n = 16), editorial/commentary without sufficient analytical content (n = 10), no health-system component (n = 8), non-English or full text unavailable (n = 5), and insufficient

extractable data or overlapping source (n = 7). Fourteen key sources were included in the final synthesis. Quality appraisal was not used as an exclusion criterion, consistent with scoping review methodology.

2.5 Data Charting

Data were charted using a structured template aligned with the six WHO health system building blocks. For each included source, the following information was extracted: first author and year; country or region; income level (HIC, LMIC, or global/multi-country); study type; WHO building block(s) addressed; climate hazard or exposure; adaptation strategies described; barriers to adaptation; enabling factors; policy or governance responses; key findings; and research or practice gaps identified. Data charting was performed by one reviewer and verified by a second reviewer, with discrepancies resolved by consensus.

2.6 Synthesis Approach

Synthesis was thematic and narrative, organized by the four review objectives. Adaptation strategies were mapped to the six WHO building blocks. Barriers and enabling factors were organized thematically by domain (financing, governance, workforce, data, infrastructure, and community/social factors). Policy and governance responses were described by geographic level (national, subnational, international). Equity findings were synthesized separately, and research gaps were compiled into a structured gap table. No quantitative pooling was performed, consistent with scoping review methodology.

3. Results

3.1 Study Selection

The study selection process is summarized in Figure 1, presented as a PRISMA-ScR flow diagram with complete counts at each stage.

3.2 Characteristics of Included Sources

Table 1 presents the characteristics of the 14 key sources included in the final synthesis, organized by first author, year, country or region, study type, WHO building block focus, and primary climate hazard addressed.

3.3 Adaptation Strategies by WHO Building Block

This review organized adaptation strategies according to the six WHO health system building blocks, as articulated in the WHO Operational Framework for Building Climate Resilient Health Systems [4]. One scoping review identified 87 discrete actions mapped to these six themes, spanning governance, financing, workforce, infrastructure, information systems, and service delivery [4]. Table 2 provides a comparative thematic mapping of adaptation strategies, country examples, and level of evidence. The following subsections describe findings for each building block in detail.

3.3.1 Leadership and Governance

Leadership and governance strategies constitute the most frequently described category of adaptation action in the reviewed literature, reflecting the foundational role of governance in enabling all other building blocks. The WHO Operational Framework identifies governance as essential for embedding climate considerations into health policy, coordinating multisectoral action, and allocating resources for adaptation [4].

Mainstreaming climate adaptation into existing health planning processes was documented in Fiji, Ghana, and Benin as countries working to integrate climate resilience into routine health policy and

implementation [2]. Tye and Waslander's analysis of these three countries highlighted governance-level efforts, including cross-ministerial steering committees, climate-health working groups, and the incorporation of adaptation objectives into national health strategic plans [2].

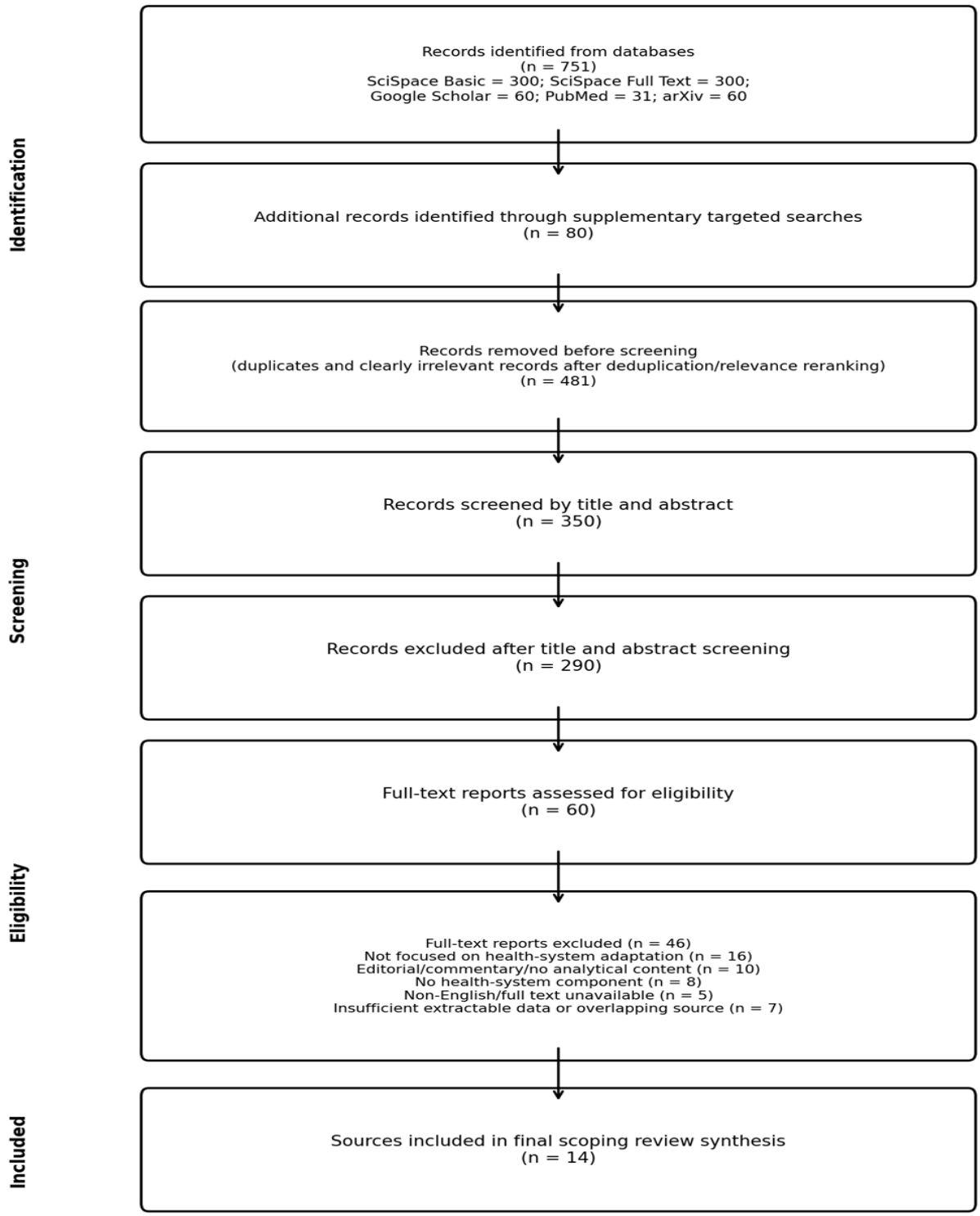

Figure 1. *PRISMA-ScR flow diagram of study selection. The diagram reports 831 records identified, 481 records removed before screening, 350 records screened, 60 full-text sources assessed, 46 full-text sources excluded with reasons, and 14 sources included in the final synthesis.*

Table 1. Characteristics of Included Sources (n=14)

Author, Year	Country/Region	Income Level	Study Type	WHO Building Block Focus	Primary Climate Hazard
Hounkpatin et al., 2024 [1]	Sub-Saharan Africa (multi-country)	LMIC	Scoping review and case study	Governance, service delivery, surveillance	Multiple (heat, floods, drought)
Tye & Waslander, 2021 [2]	Fiji, Ghana, Benin	LMIC	Policy analysis / case study	Governance, financing, service delivery	Multiple (heat, drought, flooding)
Dasgupta et al., 2016 [3]	India	LMIC	Empirical study / policy analysis	Workforce, surveillance, service delivery	Heat, floods, cyclones
Mosadeghrad et al., 2023 [4]	Global / multi-country	Mixed	Scoping review	All six building blocks	Multiple
Schwerdtle et al., 2024 [5]	LMICs (46 countries)	LMIC	Scoping review	Infrastructure, service delivery	Multiple
Schwerdtle et al., 2020 [6]	Global (humanitarian)	Mixed	Framework paper	Governance, service delivery, workforce	Multiple
Corvalan et al., 2020 [7]	Global	Mixed	Framework / policy paper	Infrastructure, workforce	Multiple
Balbus et al., 2016 [8]	Canada, USA, Latin America	HIC / LMIC	Comparative review	Infrastructure	Multiple
Ebi, 2016 [9]	Global	Mixed	Narrative review	All building blocks	Multiple
Dagneau et al., 2025 [10]	Europe (multi-country)	HIC	Empirical / framework paper	Governance, surveillance, service delivery	Extreme weather events
Smith et al., 2025 [11]	Australia (Pacific context)	HIC / LMIC	Implementation study	Workforce, governance, service delivery	Multiple
Orru et al., 2018 [12]	Estonia	HIC	Case study / empirical	Governance, surveillance	Multiple
Mauritius/Madagascar study, 2025 [13]	Mauritius, Madagascar	LMIC	Policy analysis / case study	Governance, surveillance, service delivery	Multiple
Bedi & Dresser, 2025 [14]	Canada / urban settings	HIC	Policy analysis	Infrastructure, governance	Multiple

Characteristics of the 14 key sources included in the scoping review synthesis. Sources span scoping reviews, policy analyses, framework papers, empirical studies, and implementation studies across sub-Saharan Africa, South Asia, the Pacific, Europe, North America, and global multi-country contexts. WHO = World Health Organization; LMIC = low- and middle-income country; HIC = high-income country

Table 2. Thematic Mapping of Adaptation Strategies by WHO Building Block

WHO Building Block	Adaptation Strategies Described	Country/Context Examples	Level of Evidence	Key Sources
Leadership and Governance	Mainstreaming climate into health plans; multisector coordination; Health in All Policies; interministerial collaboration; Delphi-based policy translation; participatory planning	Fiji, Ghana, Benin, Iran, Estonia	Policy analyses, case studies, framework papers	[1] [2] [4] [9] [12]
Health Financing	Targeting climate finance to frontline facilities; mobilizing domestic budgets; aligning donor inputs with national priorities; climate finance reform	Benin, LMICs globally	Policy analyses, scoping reviews	[2] [4] [5]
Health Workforce	Capacity building and training; surge staffing plans; workforce planning integrated into adaptation; sentinel clinician models; implementation science for workforce preparedness	India, Pacific Islands, Australia, Chile	Empirical studies, framework papers, implementation studies	[3] [4] [6] [11]
Medical Products, Technologies, and Infrastructure	Facility structural retrofits; water and sanitation systems; sustainable energy (solar); supply chain resilience; climate-proofing checklists; SMART Hospitals toolkit	LMICs (46 countries), Canada, USA, Latin America	Scoping reviews, comparative reviews, toolkits	[5] [7] [8]
Health Information and Surveillance	Early warning systems (EWS); climate-health data integration; BRACE framework; climate-sensitive disease surveillance; stress testing; risk documentation	Mauritius, Madagascar, Chad, Côte d'Ivoire, DRC, Rwanda, Senegal, India	Policy analyses, case studies, framework papers	[3] [4] [13]
Service Delivery	Disaster preparedness protocols; continuity of essential services; mobile/outreach services during disruptions; response-to-routine paradigms; humanitarian supply integration	India, Singapore, Pacific Islands, Estonia	Empirical studies, policy analyses, case studies	[3] [6] [10] [12]

Thematic mapping of health system adaptation strategies to climate change, organized by the six WHO health system building blocks. Strategies are drawn from the 14 key sources included in the synthesis. Evidence levels reflect the predominant study types reporting each strategy; most evidence is descriptive or framework-based rather than from controlled evaluations. BRACE = Building Resilience Against Climate Effects (CDC framework); SMART Hospitals = Safe, Sustainable, Smart, Social, and Resilient Hospitals (PAHO/WHO).

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These efforts produced enabling lessons for other LMICs, though the authors noted that international agency involvement shaped planning priorities in ways that did not always reflect locally identified needs — a dynamic they described as a risk of externally driven adaptation planning [2].

Iran's Delphi-based policy translation study represents a notable example of systematic governance operationalization, deriving 79 actionable policy items from Paris Agreement components applicable to the health sector [4]. These components encompassed stakeholder participation, vulnerable group identification, intersectoral coordination, and health system governance roles — providing a detailed template for translating international climate commitments into health system action [4].

The Health in All Policies approach and strengthened interministerial collaboration are repeatedly recommended in the literature as governance strategies to align health adaptation with infrastructure, water, and disaster management sectors [2] [9]. Ebi's narrative review emphasizes that health system resilience cannot be achieved through health sector action alone and requires sustained engagement across government ministries and with non-governmental stakeholders [9]. The WHO Operational Framework has also been adapted for humanitarian organizations, providing a governance architecture for climate-health programming in non-routine and emergency settings [6].

Estonia's case study on making administrative systems adaptive to emerging climate change-related health effects illustrates how governance adaptations can be operationalized at the national level in a high-income country context, including adjustments to regulatory frameworks, health emergency management systems, and intersectoral coordination mechanisms [12].

3.3.2 Health Financing

Health financing for climate adaptation is the most consistently identified gap in the literature and the least developed of the six building blocks in terms of documented implementation. Despite its centrality to all other adaptation actions, financing was the least discussed building block in one regional scoping review, mentioned in only 27% of sources, and was cited as a resilience gap in 24% of sources [4].

The core financing challenge identified across multiple sources is that climate finance — whether from international climate funds, donor bilateral aid, or domestic government budgets — rarely reaches health facilities and the most at-risk populations in LMICs [5]. Schwerdtle and colleagues' scoping review of LMIC facility case studies found that financing constraints were a primary barrier to implementing resilience measures at the facility level, with no documented examples of specific, evaluated financing mechanisms dedicated to health adaptation [5]. The analysis of 37 National Adaptation Plans found that only 5% of plans identified concrete climate-health funding streams or operational pathways for healthcare service delivery during extreme events — a striking gap given the centrality of financing to implementation [4].

Tye and Waslander's country case studies illustrate the complexity of the financing landscape: in Benin, international financial and technical inputs supported the planning process but may have narrowed priorities away from locally determined needs, illustrating how donor-driven financing can distort adaptation planning even as it enables it [2]. Authors across multiple sources call for sharper targeting of international climate finance to frontline health facilities, reform of climate fund access mechanisms to reduce transaction costs for health ministries, and stronger alignment between domestic health budgets and climate adaptation priorities [5] [7] [9].

3.3.3 Health Workforce

Workforce preparedness for climate change encompasses a range of strategies: training health workers on climate-related health risks; developing competency frameworks for climate-health practice; surge staffing

planning for extreme weather events; and integrating climate adaptation into health workforce planning processes.

Capacity building and skill development appear as recommended workforce strategies across multiple sources, including Iran's governance components and Pacific guidance emphasizing implementation science for workforce preparedness [4] [11]. Smith and colleagues' implementation study from Australia, with relevance to Pacific Island contexts, describes a "from policy to practice" approach to building climate-aware health systems that places workforce training and competency development at its core [11]. The study proposes sentinel clinician models — in which primary care physicians serve as monitors and responders for climate-sensitive health conditions — as an innovative approach to embedding climate awareness into routine clinical practice [11].

Dasgupta and colleagues' analysis of India's health sector preparedness identified constraints in workforce readiness for heatwaves, floods, and cyclones, including inadequate training, unclear surge staffing protocols, and limited resource planning for extreme events [3]. These findings reflect broader patterns in the LMIC literature, where workforce capacity is acknowledged as a critical bottleneck but rarely addressed through evaluated interventions [3].

The application of implementation science to workforce adaptation is increasingly advocated, particularly for Pacific Island and other resource-constrained contexts where specialist expertise is limited and health worker turnover is high [11]. Mosadeghrad and colleagues' scoping review identified workforce training as a recurrent action in national strategies and project reports, but noted that measured training outcomes and competency evaluations are not well documented in the published literature — a gap that limits understanding of what workforce interventions actually work [4].

3.3.4 Medical Products, Technologies, and Infrastructure

Infrastructure adaptation encompasses a wide range of physical and technological measures to make health facilities and supply chains more resilient to climate hazards, including structural retrofitting, sustainable energy systems, water and sanitation improvements, and supply chain resilience measures.

Schwerdtle and colleagues' scoping review of LMIC facility case studies identified 26 facility-level initiatives across 46 countries describing activities mapped to the WHO Operational Framework for climate-resilient facilities [5]. These activities included structural retrofits to protect against flooding and high winds, installation of solar energy systems to ensure power continuity during grid disruptions, improvements to water storage and sanitation infrastructure, and supply chain adaptations to maintain essential medicines and supplies during extreme events [5]. However, the review's critical finding was that there was "very little evidence of actual implementation and no evaluations of effectiveness" across the identified case studies — indicating that infrastructure adaptation is predominantly documented at the planning and design stage rather than the implementation and evaluation stage [5].

Corvalan and colleagues articulate four critical areas for climate-resilient and environmentally sustainable health care facilities: adequate skilled personnel; safe water and sanitation and waste management; sustainable and reliable energy services; and appropriate infrastructure and technologies [7]. These four areas provide a practical framework for facility-level adaptation planning and have been incorporated into several national and international toolkits.

Balbus and colleagues' comparative review of facility-level toolkits provides a useful overview of available practical resources, including the Canadian Health Care Facility Climate Change Resiliency Toolkit, the U.S. Sustainable and Climate Resilient Health Care Facilities Toolkit, and the WHO/PAHO SMART Hospitals

Toolkit [8]. Each toolkit offers checklists, asset management frameworks, and guidance for energy, water, and structural adaptations, though the authors note that uptake and implementation evidence remain limited [8]. Bedi and Dresser's analysis of health care, cities, and climate change highlights the particular challenges of urban health infrastructure adaptation, including the intersection of climate risk, built environment, and health system capacity in rapidly urbanizing settings [14].

3.3.5 Health Information and Surveillance Systems

Strengthening health information and surveillance systems for climate-sensitive conditions is a widely recommended adaptation strategy, encompassing early warning systems (EWS), climate-health data integration, climate-sensitive disease surveillance, and structured risk assessment frameworks.

The analysis of 37 National Adaptation Plans found that almost half recognized the importance of risk monitoring and early warning systems, reflecting a broad policy consensus on the value of surveillance for adaptation [4]. Mauritius represents a notable example of advanced EWS implementation, with a multi-sector Early Warning Alert and Response System supported by partnerships across health, meteorology, and disaster management agencies [13]. Madagascar has piloted a "Climate-Smart Public Health" approach incorporating data-driven surveillance innovations and climate-informed health risk assessments in targeted settings [13]. In sub-Saharan Africa, national malaria programmes in Chad, Côte d'Ivoire, the Democratic Republic of Congo, Madagascar, Rwanda, and Senegal have described integrating climate and health data and strengthening surveillance and early warning as adaptive strategies, though systemic barriers and limited outcome data remain [1].

The CDC's Building Resilience Against Climate Effects (BRACE) framework provides a five-step operational process for public health agencies to project climate impacts, assess vulnerabilities, develop and implement adaptation strategies, evaluate effectiveness, and communicate results [4]. The BRACE framework explicitly links surveillance and epidemiological modelling to action planning and adaptive management, making it a practical tool for integrating climate considerations into routine public health practice. Dagneau and colleagues' analysis of health system resilience in the face of extreme weather events provides complementary guidance on stress testing — a structured process for examining health system capacity under extreme or novel climate scenarios that draws on surveillance data, stakeholder engagement, and scenario analysis [10].

Dasgupta and colleagues identified significant gaps in systematic documentation of morbidity and mortality linked to climatic events in India, highlighting the practical consequences of weak surveillance for adaptation planning: without reliable data on climate-health impacts, prioritization of interventions and allocation of resources are necessarily ad hoc [3].

3.3.6 Service Delivery

Service delivery adaptations aim to maintain the continuity and quality of essential health services during and after climate-related disruptions, including extreme weather events, disease outbreaks, and infrastructure failures.

Disaster preparedness and continuity of care are the most commonly described service delivery adaptation strategies in the reviewed literature. Dasgupta and colleagues' analysis of India's preparedness for heatwaves, floods, and cyclones emphasized the need for formal disaster preparedness protocols, clear lines of responsibility for health service continuity, and pre-positioned supplies and personnel [3]. Smith and colleagues' implementation study advocates for embedding climate awareness into routine primary care

delivery, including through sentinel clinician networks that monitor climate-sensitive conditions and trigger escalation responses [11].

The reviewed resilience literature also supports a "response-to-routine" approach, in which lessons from emergency preparedness, stress testing, and continuity planning are integrated into routine service delivery for vulnerable groups, including older adults and people with chronic or complex health needs [10].

Orru and colleagues' case study of Estonia's administrative adaptation to climate change-related health effects documents how service delivery systems can be made more responsive to emerging climate risks through regulatory adjustments, enhanced interagency coordination, and the integration of climate projections into health emergency management planning [12]. The study illustrates that high-income country health systems face their own adaptation challenges, including the need to update ageing infrastructure, retrain workforces, and redesign service delivery protocols for novel climate hazards.

3.4 Barriers and Enabling Factors

Table 3 provides a structured summary of barriers, enabling factors, policy responses, and research gaps. The following subsections describe findings by thematic domain.

Table 3. Barriers, Enabling Factors, Policy Responses, and Research Gaps in Health System Climate Adaptation

Domain	Barriers	Enabling Factors	Policy Responses	Research Gaps
Financing	Climate finance rarely reaches frontline facilities [5]; only 5% of NAPs identify funding streams [4]; donor-driven priorities misaligned with local needs [2]	Sharper targeting of international funding; domestic budget alignment; business cases for resilience investment [5] [8]	Health National Adaptation Plans; climate fund access reform; SMART Hospitals financing guidance [2] [8]	Lack of evaluated financing instruments; no documented cost-effectiveness of specific mechanisms
Governance and Political Will	Policy mimicry from externally driven planning [2]; weak multisector coordination; lack of sustained implementation [2]	Mainstreaming climate into health plans [2]; Health in All Policies; interministerial collaboration [9]; Delphi-based policy translation [4]	National adaptation plans (Benin, Fiji, Ghana) [2]; Iran's 79-component governance framework [4]; Estonia's administrative adaptation [12]	Lack of policy outcome evaluations; limited evidence on governance effectiveness
Health Workforce	Limited training and competency in climate-health [3]; surge planning gaps [3]; high turnover in LMICs	Implementation science for workforce preparedness [11]; sentinel clinician models [11]; capacity building programmes [4]	Workforce components in HNAPs; WHO climate-health competency guidance	No quantitative evaluations of workforce training outcomes; limited competency frameworks
Data and Surveillance	Inadequate documentation of climate-health impacts [3]; fragmented data systems; non-	BRACE framework for modelling and risk assessment [4]; climate-health data integration; EWS	Surveillance components in NAPs; BRACE adoption in public health agencies	Insufficient outcome data from EWS; no rigorous evaluations of surveillance system

	standardized reporting	(Mauritius) [13]		effectiveness
Infrastructure	Insufficient evidence to prescribe specific measures [8]; fragile supply chains; limited implementation of facility upgrades [5]	Toolkits (Canadian, U.S., PAHO SMART Hospitals) [8]; WHO four critical areas framework [7]; 26 LMIC facility case studies [5]	Facility-level toolkits; SMART Hospitals programme; national infrastructure standards	Very little evidence of actual implementation; no effectiveness evaluations in LMICs [5]
Community and Equity	Narrowly driven planning missing local needs [2]; climate finance not reaching vulnerable communities [5]	Community engagement as cross-cutting enabler [5]; gendered vulnerability analysis [13]; equity-focused planning [4]	Vulnerable group identification in HNAPs; community engagement frameworks	Insufficient evidence on equity outcomes; no quantitative equity impact evaluations

Summary of barriers, enabling factors, policy responses, and research gaps in health system adaptation to climate change, organized by domain. Evidence is drawn from the 14 key sources included in the synthesis. NAPs = National Adaptation Plans; HNAPs = Health National Adaptation Plans; EWS = Early Warning Systems; BRACE = Building Resilience Against Climate Effects; SMART Hospitals = Safe, Sustainable, Smart, Social, and Resilient Hospitals.

3.4.1 Financing Barriers and Enablers

Inadequate, misaligned, or inaccessible financing is the most consistently identified barrier to health system climate adaptation across the reviewed literature. Authors repeatedly find that climate finance, despite growing in volume globally, rarely reaches health facilities and the most at-risk populations in LMICs [5]. Schwerdtle and colleagues' scoping review of LMIC facility case studies found that financing constraints were a primary barrier to implementing resilience measures, with no documented examples of specific, evaluated financing mechanisms dedicated to health adaptation [5]. The analysis of 37 National Adaptation Plans found that only 5% identified concrete climate-health funding streams — a striking gap that reflects the persistent disconnect between adaptation planning and financing [4].

Donor-driven financing can compound this problem: Tye and Waslander found that in Benin, international financial and technical inputs supported the planning process but may have narrowed priorities away from locally determined needs, illustrating how external financing can simultaneously enable and constrain locally responsive adaptation [2]. Authors call for sharper targeting of international climate finance to frontline health facilities, reform of climate fund access mechanisms, and stronger alignment between domestic health budgets and adaptation priorities [5] [7] [8].

3.4.2 Governance and Political Will

Weak multisector coordination, dominance of external actors in planning processes, and lack of sustained policy implementation are common governance barriers identified in the literature. Tye and Waslander's analysis of Benin's NAP process noted that the dominant roles of global agencies in steering adaptation planning can produce "policy mimicry" — the adoption of internationally recognized frameworks without adequate adaptation to local contexts — and limit the development of locally responsive plans [2]. The sub-Saharan Africa scoping review similarly found that governance challenges, including fragmented health systems, limited institutional capacity, and competing health priorities, constrained adaptation action across the region [1].

Enabling governance factors include mainstreaming climate adaptation into existing health planning processes, Health in All Policies approaches, and structured policy translation exercises. Fiji, Ghana, and

Benin's mainstreaming efforts produced concrete governance actions and lessons for implementation [2]. Iran's Delphi-based policy translation produced 79 governance components to operationalize international agreements for the health sector [4]. Estonia's case study illustrates how administrative systems can be made adaptive through regulatory reform and enhanced interagency coordination [12].

3.4.3 Workforce and Capacity

Limited workforce capacity, training gaps, and surge planning constraints are repeatedly reported as barriers to effective adaptation, particularly in LMICs. Dasgupta and colleagues identified constraints in workforce preparedness for heatwaves, floods, and cyclones in India, including inadequate training, unclear surge staffing protocols, and limited resource planning for extreme events [3]. The absence of standardized competency frameworks for climate-health practice means that workforce development efforts are often ad hoc and poorly evaluated.

Enabling factors for workforce adaptation include the application of implementation science to identify barriers to uptake and scale effective interventions, sentinel clinician models that embed climate awareness into routine clinical practice, and structured capacity building programmes linked to national adaptation plans [11] [4]. Smith and colleagues' "from policy to practice" approach advocates for grounding workforce development in local context and building on existing health system structures rather than creating parallel training systems [11].

3.4.4 Data and Information Systems

Poor documentation of climate-health impacts, fragmented data systems, and lack of standardized reporting impede adaptation planning across settings. Dasgupta and colleagues highlighted gaps in systematic documentation of morbidity and mortality linked to climatic events in India, noting that without reliable data on climate-health impacts, prioritization of interventions and resource allocation are necessarily ad hoc [3]. The absence of standardized reporting frameworks means that lessons from adaptation initiatives are rarely shared or built upon.

Enabling factors for information system strengthening include the BRACE framework's approach to modelling and iterative risk assessment, climate-health data integration initiatives such as those in Mauritius and Madagascar, and the integration of climate projections into routine health information systems [4] [13]. Dagneau and colleagues' stress testing guidance provides a structured approach to examining health system capacity under extreme climate scenarios that can inform both surveillance design and adaptation planning [10].

3.4.5 Infrastructure and Supply Chains

Fragile infrastructure and supply chains are major barriers to resilient service delivery, particularly in LMICs where health facilities may lack reliable electricity, clean water, and structurally sound buildings. Historical risk assessments concluded that there was insufficient evidence to define specific infrastructure adaptation measures, calling for integration with asset management and disaster management systems [8]. Schwerdtle and colleagues' scoping review found that despite 26 LMIC facility case studies describing infrastructure adaptation activities, there was "very little evidence of actual implementation and no evaluations of effectiveness" — indicating that infrastructure adaptation is predominantly documented at the planning stage [5].

Enabling factors include the availability of practical toolkits (Canadian, U.S., and PAHO SMART Hospitals) that provide checklists and asset management frameworks for energy, water, and structural adaptations [8],

and Corvalan and colleagues' articulation of four critical areas for climate-resilient facilities [7]. The challenge is translating these tools into implemented, evaluated interventions at scale.

3.4.6 Community and Social Factors

Community engagement and attention to social vulnerability are identified as necessary enablers of effective adaptation, yet narrowly driven planning processes frequently miss local needs and the priorities of vulnerable groups. Tye and Waslander noted that externally driven planning in Benin risked overlooking locally identified adaptation needs [2]. The sub-Saharan Africa scoping review found that community engagement and participatory planning were important enablers where they were present, but were not consistently incorporated into adaptation planning processes [1].

Schwerdtle and colleagues' LMIC facility review highlighted community engagement as a cross-cutting enabler and recommended its inclusion in resilience frameworks and action plans [5]. The Mauritius and Madagascar policy analysis emphasized community participation and gendered vulnerability analysis as essential components of resilient health system design [13].

3.5 Policy and Governance Responses

The literature documents a range of national, subnational, and international policy and governance responses to the challenge of building climate-resilient health systems, spanning national adaptation plans, international frameworks and toolkits, and multisectoral governance approaches.

National adaptation plans and health mainstreaming: Benin's National Adaptation Plan, developed with international agency support, prioritized heat, drought, and flooding as key climate hazards and integrated health sector adaptation into national planning processes [2]. Fiji and Ghana undertook similar mainstreaming efforts, documenting governance-level actions and lessons for other LMICs [2]. Iran's health policy translation exercise used Delphi consensus methods to map Paris Agreement elements into 79 health system components for action, producing a detailed governance framework for operationalizing international climate commitments at the national level [4]. An analysis of 37 NAPs published in English through 2023 found high variability in how strategic goals mapped to operational priorities, with evaluation and monitoring absent as implementation objectives in the majority of plans [4].

International frameworks and toolkits: The WHO Operational Framework for Building Climate Resilient Health Systems provides the overarching architecture for adaptation planning, with its six building blocks serving as the organizing structure for this review and for multiple country-level assessments and toolkits [4]. The CDC's BRACE framework provides operational guidance for public health agencies to model climate impacts and prioritize interventions [4]. Balbus and colleagues' comparative review of facility-level toolkits identifies the Canadian, U.S., and PAHO SMART Hospitals toolkits as practical starting points for facility-level policy and asset planning [8]. Schwerdtle and colleagues adapted the WHO Framework for humanitarian organizations, extending its applicability to emergency and fragile settings [6].

Multisectoral governance approaches: Health in All Policies and interministerial collaboration are repeatedly recommended as governance strategies to align health adaptation with infrastructure, water, and disaster management sectors [2] [9]. Estonia's case study illustrates how administrative systems can be made adaptive through regulatory reform and enhanced interagency coordination [12]. Dagneau and colleagues' analysis of resilience in the face of extreme weather events emphasizes the value of structured stress testing as a governance tool for examining health system capacity and identifying adaptation priorities [10].

Policy outcomes and evaluation evidence: The reviewed literature documents planning outputs — NAPs, toolkits, consensus components, governance frameworks — but contains limited empirical evaluation of policy outcomes or measured improvements in health system resilience following policy adoption [5] [2]. This evaluation gap is itself a major finding of this review and a priority for future research.

3.6 Health Equity and Vulnerability

Climate change does not affect all populations equally. The reviewed literature consistently emphasizes that climate impacts are unevenly distributed and that vulnerable populations — defined geographically, socioeconomically, and demographically — face higher exposure, greater sensitivity, and lower adaptive capacity than more advantaged groups.

Geographic vulnerability: Sub-Saharan Africa and small island states are highlighted across multiple sources as facing disproportionate climate risk combined with constrained health system capacity [1]. Hounkpatin and colleagues' scoping review found that sub-Saharan health systems face particular challenges in adapting to climate change, including fragmented health systems, limited financing, and a sparse evidence base on adaptation strategies specific to the region [1]. Small island developing states face existential threats from sea-level rise and intensifying tropical cyclones that directly threaten health infrastructure and service continuity.

Socioeconomic vulnerability: LMIC health facilities and underserved communities are repeatedly noted as less able to access climate finance and implement infrastructure upgrades, increasing their vulnerability to climate disruption [5]. The financing gap is both a cause and a consequence of socioeconomic vulnerability: communities with the least resources face the greatest climate risks but have the least capacity to mobilize adaptation finance.

Demographic vulnerability: Older adults, children, pregnant women, people with chronic conditions, and those with disabilities are repeatedly identified as particularly vulnerable to climate-related health impacts and service disruptions [10]. The Mauritius and Madagascar policy analysis emphasizes gendered vulnerability, noting that women and girls often face disproportionate climate-health burdens due to their roles in household water and food provisioning and their limited access to formal health services [13].

Equity-focused adaptation strategies: Across the reviewed literature, equity-focused adaptation strategies include: identifying and prioritizing vulnerable groups in planning processes [4] [2]; directing climate finance to high-risk communities and frontline facilities [5]; ensuring community engagement in adaptation planning to reflect local needs and priorities [5]; and designing service delivery adaptations that specifically address barriers faced by marginalized groups, such as mobile health services, community health worker outreach, and telehealth for remote populations [11].

Despite these recommendations, the reviewed literature lacks measured outcomes demonstrating reductions in health inequities attributable to specific adaptation interventions. The evidence base on equity outcomes of climate adaptation remains largely descriptive and normative, calling for targeted research that disaggregates adaptation outcomes by socioeconomic, geographic, and demographic dimensions.

3.7 Research and Practice Gaps

The reviewed literature consistently identifies a substantial gap between the growing portfolio of adaptation frameworks, plans, and toolkits and the evidence of their implementation and effectiveness. Table 3 summarizes research and practice gaps by domain. The following key gaps are highlighted:

Implementation and evaluation deficit: Schwerdtle and colleagues' scoping review of LMIC facility case studies identified 26 initiatives but found "very little evidence of actual implementation and no

evaluations of effectiveness" — a finding that encapsulates the broader implementation gap in health system climate adaptation [5]. Most literature provides frameworks, case descriptions, and recommendations rather than impact evaluations, limiting the ability of policymakers to identify what interventions actually work and under what conditions.

Sparse regional evidence: Hounkpatin and colleagues' sub-Saharan Africa scoping review found only 14 papers meeting inclusion criteria, indicating a niche literature that is poorly matched to the region's high climate vulnerability and health burden [1]. Similar gaps likely exist for other high-burden regions, including South Asia, Southeast Asia, and the Pacific.

Insufficient health impact data: Dasgupta and colleagues highlighted gaps in systematic documentation of morbidity and mortality linked to climatic events in India, a finding that reflects broader weaknesses in climate-health surveillance globally [3]. Without reliable data on climate-health impacts, adaptation planning lacks an evidence base for prioritization.

Limited infrastructure evidence: Early risk assessments concluded that insufficient evidence existed to support specific, well-defined infrastructure adaptation strategies [8]. Despite the proliferation of toolkits and case studies since then, Schwerdtle and colleagues' 2024 review confirms that rigorous evaluations of infrastructure interventions remain absent from the published literature [5].

Financing and governance evaluation: Targeted evaluations of financing mechanisms and governance models are needed to assess whether donor and domestic funding instruments improve frontline resilience and equity [5] [2]. The finding that only 5% of 37 NAPs identified concrete climate-health funding streams underscores the urgency of this research priority [4].

Implementation science application: Smith and colleagues advocate for the application of implementation science frameworks to test, scale, and adapt interventions in Pacific and other resource-constrained contexts [11]. This approach — which systematically identifies barriers to uptake, tests implementation strategies, and monitors fidelity and outcomes — is underutilized in health system climate adaptation and represents a significant methodological opportunity.

4. Discussion

4.1 Principal Findings

This scoping review mapped the peer-reviewed and grey literature on health system adaptation to climate change, identifying adaptation strategies, barriers, enabling factors, policy responses, and research gaps across 14 key sources spanning diverse geographic and methodological contexts. The principal findings are that: (1) a growing portfolio of adaptation strategies is described across all six WHO health system building blocks, but implementation and evaluation remain sparse; (2) financing is the most consistently identified barrier, with climate finance rarely reaching frontline facilities; (3) governance responses are predominantly at the planning and framework stage, with limited evidence of policy outcomes; (4) health equity concerns are prominent but poorly addressed in the evidence base; and (5) the most critical research gap is the absence of rigorous evaluations of adaptation interventions' effects on health outcomes and system resilience.

4.2 The WHO Framework as an Organizing Architecture

The WHO Operational Framework for Building Climate Resilient Health Systems has emerged as the dominant organizing architecture for health system climate adaptation, with its six building blocks providing a common language and structure for country assessments, toolkits, and planning documents [4].

Mosadeghrad and colleagues' scoping review identified 87 discrete adaptation actions mapped to these six themes, demonstrating the framework's utility as a comprehensive taxonomy of adaptation strategies [4]. The framework has been applied in country-level analyses in Fiji, Tanzania, and other settings, and adapted for humanitarian organizations, illustrating its flexibility across contexts [6].

However, the framework's wide adoption has not translated into widespread implementation or evaluation. The literature documents a persistent gap between the framework's conceptual comprehensiveness and the evidence of its practical application. Most sources describe planning-stage activities — assessments, toolkits, NAPs, governance frameworks — rather than implemented, evaluated interventions. This implementation gap is itself a significant finding that calls for investment in implementation science and rigorous evaluation alongside continued framework development.

4.3 The Financing Gap

The financing gap is arguably the most consequential barrier to health system climate adaptation identified in this review. The finding that climate finance rarely reaches health facilities and frontline populations [5], that only 5% of 37 NAPs identify concrete funding streams [4], and that financing is the least discussed building block in regional reviews [4] collectively paint a picture of a field where planning has outpaced resourcing. This gap is particularly acute in LMICs, where health systems face the greatest climate risks but have the least capacity to mobilize adaptation finance.

Addressing the financing gap requires action at multiple levels: reform of international climate fund access mechanisms to reduce transaction costs and increase health sector allocations; strengthening of domestic health budget processes to integrate climate adaptation priorities; alignment of donor financing with locally determined needs rather than externally driven frameworks; and development of innovative financing instruments, such as climate-health bonds, parametric insurance, and results-based financing, that can channel resources to frontline adaptation activities. The near-total absence of evaluated financing instruments in the published literature is a critical gap that must be addressed if the field is to move from planning to implementation.

4.4 Workforce Preparedness

Workforce preparedness for climate change is a cross-cutting enabler of adaptation across all building blocks, yet it is among the least evaluated dimensions of health system adaptation. The reviewed literature identifies workforce training, surge planning, and competency development as recurrent actions in national strategies, but measured training outcomes and competency evaluations are not well documented [4]. This evaluation gap limits understanding of what workforce interventions are effective and how they should be designed, delivered, and scaled.

Innovative approaches such as sentinel clinician models [11] and implementation science-informed workforce development [11] offer promising directions, but require rigorous evaluation before they can be confidently recommended for scale-up. The development of standardized competency frameworks for climate-health practice — analogous to those that exist for emergency medicine, infectious disease, or environmental health — would provide a foundation for consistent workforce development and evaluation across settings.

4.5 Surveillance, Information, and Early Warning

Strengthening health information and surveillance systems for climate-sensitive conditions is widely recognized as a priority adaptation strategy, yet the evidence base on the effectiveness of specific surveillance interventions remains thin. The BRACE framework and similar approaches provide structured

guidance for linking surveillance and modelling to action planning [4], and country examples such as Mauritius's multi-sector EWS [13] and Madagascar's Climate-Smart Public Health approach [13] illustrate what advanced surveillance can look like in practice. However, rigorous evaluations demonstrating that surveillance system improvements translate into better health outcomes or more effective adaptation responses are absent from the reviewed literature.

This evaluation gap is compounded by the data deficits identified in settings such as India, where inadequate documentation of climate-health impacts limits the evidence base for adaptation planning [3]. Addressing this gap requires investment in routine health information systems that can capture climate-sensitive morbidity and mortality data, standardized reporting frameworks that enable cross-country comparison and learning, and research that rigorously evaluates the health outcomes of surveillance-based adaptation.

4.6 Governance, Policy, and the Implementation Deficit

The governance and policy landscape for health system climate adaptation is characterized by a proliferation of frameworks, plans, and toolkits alongside a persistent implementation deficit. National adaptation plans have been developed in multiple countries, international frameworks such as BRACE and the WHO Operational Framework provide operational guidance, and consensus-based policy translation exercises have produced detailed governance components [4]. Yet the literature documents planning outputs rather than policy outcomes, and evaluation of governance interventions is largely absent.

The implementation deficit has several causes. First, governance frameworks are often developed through externally driven processes that prioritize internationally recognized templates over locally responsive planning [2]. Second, financing gaps mean that even well-designed plans cannot be implemented. Third, weak monitoring and evaluation systems mean that even implemented interventions are not systematically assessed. Fourth, the multisectoral nature of health system climate adaptation — which requires coordination across health, environment, infrastructure, water, and disaster management sectors — creates coordination challenges that single-ministry governance structures are ill-equipped to address.

Addressing the implementation deficit requires investment in implementation science, which provides frameworks and methods for understanding and overcoming barriers to the adoption, fidelity, and sustainability of evidence-based interventions [11]. It also requires governance reforms that strengthen accountability, monitoring, and evaluation; financing reforms that align resources with priorities; and community engagement processes that ensure adaptation plans reflect local needs and contexts.

4.7 Health Equity

Health equity is a cross-cutting concern that runs through all dimensions of health system climate adaptation. The reviewed literature consistently documents that climate change exacerbates existing health inequities, with the most vulnerable populations — geographically, socioeconomically, and demographically defined — facing the greatest climate risks and the least adaptive capacity [1] [5]. Yet the evidence base on equity outcomes of adaptation interventions is largely descriptive and normative, lacking the measured outcomes needed to demonstrate that adaptation actions are actually reducing health inequities.

This equity evidence gap has practical consequences: without data on which populations are reached by adaptation interventions, and whether adaptation reduces or widens health disparities, policymakers cannot make evidence-informed decisions about how to design equitable adaptation programmes. Addressing this gap requires research designs that explicitly measure equity outcomes, disaggregating results by socioeconomic status, geographic location, gender, age, disability status, and other dimensions of vulnerability. It also requires adaptation programme designs that build equity considerations in from the start, rather than treating equity as an afterthought.

4.8 Strengths and Limitations

This review has several strengths. It employed a systematic, multi-database search strategy with multiple query variations per database, maximizing coverage of the available literature. It followed the PRISMA-ScR framework, ensuring methodological transparency. It organized findings according to the established WHO building blocks framework, enabling structured comparison across building blocks and facilitating policy relevance. It synthesized evidence across diverse geographic and methodological contexts, providing a global perspective on health system climate adaptation.

The review also has limitations. The synthesis drew on 14 key sources, which, while methodologically diverse and geographically representative, does not constitute an exhaustive review of all available literature. The scoping review design does not include quality appraisal of included sources, meaning that findings from weaker studies are treated equivalently to those from stronger studies. The search was conducted in English only, potentially excluding relevant literature in other languages. The rapidly evolving nature of the field means that relevant publications may have appeared after the search date. Finally, the predominance of planning-stage and framework-based literature in the evidence base means that this review maps what has been described and recommended more than what has been implemented and evaluated — a reflection of the state of the field rather than a limitation of the review methodology.

5. Conclusion

This scoping review has mapped the literature on health system adaptation to climate change, identifying a growing portfolio of adaptation strategies across the six WHO health system building blocks, alongside persistent barriers, emerging policy responses, and critical research and practice gaps. The review demonstrates that the conceptual architecture for climate-resilient health systems is well developed — anchored in the WHO Operational Framework and operationalized through national adaptation plans, international toolkits, and consensus-based governance frameworks — but that implementation and evaluation remain profoundly underdeveloped.

The most urgent priorities for the field are: closing the financing gap by reforming climate fund access mechanisms and aligning domestic health budgets with adaptation priorities; investing in implementation science to test, scale, and evaluate adaptation interventions; strengthening health information and surveillance systems to generate the data needed for evidence-informed adaptation planning; developing standardized competency frameworks for climate-health workforce development; and designing adaptation programmes with equity as a core objective, supported by research that disaggregates outcomes by dimensions of vulnerability.

For global public health practice and health systems, these findings have direct implications. Health systems that fail to adapt to climate change will face increasing disruptions to service delivery, growing burdens of climate-sensitive disease, and widening health inequities. Health systems that invest in climate resilience — through governance reform, financing, workforce development, infrastructure adaptation, and surveillance strengthening — will be better positioned to protect population health under conditions of increasing environmental stress. The evidence base reviewed here, while limited in terms of evaluated outcomes, provides a foundation for action and a roadmap for the research investments needed to build that evidence base.

The global health community, national governments, international organizations, and civil society must work together to close the gap between the growing ambition of health system climate adaptation and the limited evidence of its implementation and effectiveness. This scoping review is intended as a contribution to that

effort — mapping what is known, identifying what is not, and pointing toward the research and policy investments needed to build truly climate-resilient health systems for the twenty-first century.

Acknowledgements

The author acknowledges the contributions of all researchers and institutions whose work informed this review.

AI Declaration

The author declares that artificial intelligence (AI) tools were used solely to assist with language editing, grammar refinement, and improvement of clarity and readability. AI tools did not generate original data, analyses, or scientific interpretations. All content was critically reviewed, revised, and approved by the author, who takes full responsibility for the accuracy and integrity of the manuscript

Funding

The authors received no specific funding for this work.

Conflicts of Interest

The authors declare no conflicts of interest.

Author Contributions

All authors contributed to the conception, design, data extraction, analysis, and manuscript preparation.

References

1. Hounkpatin H, Nieto-Sanchez C, Castellano Pleguezuelo V, et al. How are health systems in sub-Saharan Africa adapting to protect human health from climate change threats? A scoping review and case study. Lancet Planet Health. 2024;8(4):e248–e261. doi:10.1016/S2542-5196(24)00075-5
2. Tye S, Waslander J. Mainstreaming Climate Adaptation Planning and Action into Health Systems in Fiji, Ghana, and Benin. Washington DC: World Resources Institute; 2021. doi:10.46830/WRIWP.19.00119
3. Dasgupta P, Ebi KL, Sachdeva I. Health sector preparedness for adaptation planning in India. Clim Change. 2016;138(3–4):467–480. doi:10.1007/s10584-016-1745-7
4. Mosadeghrad AM, Isfahani P, Eslambolchi L, et al. Strategies to strengthen a climate-resilient health system: a scoping review. Global Health. 2023;19(1):72. doi:10.1186/s12992-023-00965-2
5. Schwerdtle PN, Ngo TA, Hasch F, et al. Climate change resilient health facilities: a scoping review of case studies in low and middle-income countries. Environ Res Lett. 2024;19(6):064038. doi:10.1088/1748-9326/ad472b
6. Schwerdtle PN, Irvine E, et al. Calibrating to scale: a framework for humanitarian health organizations to anticipate, prevent, prepare for and manage climate-related health risks. Global Health. 2020;16(1):60. doi:10.1186/s12992-020-00582-3

7. Corvalan C, Villalobos Prats E, Sena A, et al. Towards Climate Resilient and Environmentally Sustainable Health Care Facilities. Int J Environ Res Public Health. 2020;17(23):8849. doi:10.3390/ijerph17238849

8. Balbus J, Berry P, Brettle M, et al. Enhancing the sustainability and climate resiliency of health care facilities: a comparison of initiatives and toolkits. Rev Panam Salud Publica. 2016;40(3):154–163.

9. Ebi KL. Adaptation and resilience. Public Health Rev. 2016;37(1):1–9. doi:10.1186/s40985-016-0032-5

10. Dagneau E, Ehgartner SM, Guliš G. Bridging the Gap Between Climate and Health Systems: The Value of Resilience in Facing Extreme Weather Events. Int J Environ Res Public Health. 2025;22(8):1258. doi:10.3390/ijerph22081258

11. Smith CL, Rojas C, Zurynski Y, et al. From policy to practice: building a resilient, climate aware health system from the ground up. Clim Change. 2025;178(3). doi:10.1007/s10584-025-03914-7

12. Orru K, Tillmann M, Ebi KL, et al. Making Administrative Systems Adaptive to Emerging Climate Change-Related Health Effects: Case of Estonia. Atmosphere. 2018;9(6):221. doi:10.3390/atmos9060221

13. Resilient Health Systems under Environmental Stress: Policy Lessons from Mauritius and Madagascar. Adv Earth Environ Sci. 2025. doi:10.47485/2766-2624.1082

14. Bedi NS, Dresser C. Health Care, Cities, and Climate Change: Challenges and Opportunities. J Clim Change Public Health. 2025. doi:10.3138/jccpe-2024-0038