Delivering the Belém Health Action Plan

COP30 SPECIAL REPORT ON
HEALTH AND CLIMATE CHANGE

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Preliminary Version

Delivering the Belém Health Action Plan: COP30 Special Report on Health and Climate Change

ISBN pending (electronic version)
ISBN pending (print version)

Suggested citation. Delivering the Belém Health Action Plan: COP30 Special Report on Health and Climate Change. Geneva: World Health Organization; 2025. Licence: .

Cataloguing-in-Publication (CIP) data. CIP data are available at http://apps.who.int/iris.

1st Edition – 2025 – Preliminary electronic version

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Contents

Foreword

Climate change is an unavoidable reality that challenges public health, threatens historic health achievements, and adds pressure on already overwhelmed systems. Worldwide, extreme events, emerging health threats and emergencies, and major environmental changes place the health sector at the forefront of the most strategic decisions of the 21st century. Protecting lives, reducing inequalities, and bolstering the resilience of health systems are no longer just goals—they have become ethical and democratic imperatives. Brazil recognizes that addressing the climate crisis is also about defending the universal right to health.

International cooperation and scientific knowledge are essential pillars for understanding new epidemiological patterns, enhancing health surveillance, forecasting risks, and developing social and medical technologies that promote resilience and sustainability.

The COP30 Special Report on Health and Climate Change provides the evidence that underpins the implementation of the Belém Health Action Plan (BHAP), an initiative that places health at the forefront of the global adaptation response to the climate crisis. It provides resources to assist countries that endorse the Plan, as well as other stakeholders involved in its voluntary implementation, based on local needs and realities.

Developed with the support of the Ministry of Health of Brazil and the World Health Organization (WHO), and produced by a global Expert Advisory Group chaired by the Center for Sustainable Medicine at the National University of Singapore, this document brings together scientific evidence and experiences from diverse national health systems. It provides evidence that effective and readily available solutions for adaptation can be implemented immediately, while emphasizing the need to increase funding for the health sector, recognizing the central role of health in the global climate agenda.

In presenting this report, we reaffirm that evidence-based decision-making is the most effective way to guide policies, inspire cooperation, and develop sustainable solutions. The document invites governments, institutions, and other stakeholders to use it as a reference to strengthen adaptation strategies, expand scientific knowledge, and advance the construction of more resilient, equitable, and future-ready health systems.

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Acknowledgements

The Ministry of Health of Brazil and the World Health Organization (WHO) would like to express appreciation for the following institutions, experts and partners who contributed to the preparation of this COP30 Special Report on Health and Climate Change.

The development and production of this Special Report and the Belém Health Action Library was led by Nick Watts, Mita Huq, Elizabeth Siobhan Loke Hui Zhen, Jit Sohal, Thomas Andrew, E-Sean Lum, Chantelle Rizan, and Aruzhan Shalabayeva at the NUS Centre for Sustainable Medicine.

Invaluable support and coordination was provided by Agnes Soares da Silva, Nanny Santana Leal de Figueiredo, and Clara Alves Silva at the Ministry of Health of Brazil, and by Marina Maiero, Alexandra Egorova, Olena Zotova, Rita Issa, Elena Villalobos Prats, Christian Schweizer, Frank Pega, Paul Safar, Samantha Pegoraro, and Diarmid Campbell-Lendrum at WHO. Owen Landeg in the Greener NHS team provided coordination support and expert review of the Belém Health Action Library, and Portia Lapidario is responsible for the document's formatting and design.

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Finally, utmost gratitude is extended to the global climate and health community, including the many experts, the members of the Alliance for Transformative Action on Climate and Health (ATACH), and partner institutions who provided evidence, case studies, photographs and perspectives that serve as the backbone of this report. Special thanks are due to Wellcome, the World Bank, the Asian Development Bank, the Asian Infrastructure Investment Bank, the Rockefeller Foundation and the Global Climate and Health Alliance for their consultative review throughout the process.

Acronyms

ADB	Asian Development Bank
AfDB	African Development Bank
AIIB	Asian Infrastructure Investment Bank
ATACH	Alliance for Transformative Action on Climate and Health
BHAL	Belém Health Action Library
CO_2e	Carbon dioxide equivalent
COP	Conference of the Parties
EWS	Early warning system(s)
GCF	Green Climate Fund
GCHA	Global Climate and Health Alliance
GCCHE	Global Consortium on Climate and Health Education
GDP	Gross domestic product
GHG	Greenhouse gas(es)
HDI	Human Development Index
HIS	Health information system(s)
HNAP	Health National Adaptation Plan
ICJ	International Court of Justice
IPCC	Intergovernmental Panel on Climate Change
LDCF	Least Developed Countries Fund
LDC	Least Developed Country
LMICs	Low- and middle-income countries
MDB	Multilateral development bank(s)
M&E	Monitoring and evaluation
MHEWS	Multi-hazard early warning system(s)
NAP(s)	National Adaptation Plan(s)
NDC(s)	Nationally Determined Contribution(s)
NGO(s)	Non-governmental organization(s)
PHRC	Planetary Health Report Card
RBF	Results-based finance
RCP	Representative Concentration Pathway
SIDS	Small Island Developing States
SSP	Shared Socioeconomic Pathway
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
US$	United States dollar
V&A	Vulnerability and adaptation (assessment)
WASH	Water, sanitation, and hygiene
WBG	World Bank Group
WHA	World Health Assembly
WHO	World Health Organization
WMO	World Meteorological Organization

Executive summary

The World Health Organization and The Lancet agree: climate change presents the most significant threat to human health of this century. Nearly half the world's population – 3.3 to 3.6 billion people – now live in highly climate-vulnerable contexts, and 1 in 12 of the world's 200 000 hospitals face the risk of total shutdown due to extreme weather events under high-emissions scenarios.

This COP30 Special Report on Health and Climate Change, presented by the Ministry of Health of Brazil and the World Health Organization, serves as the evidence base that underpins the **Belém Health Action Plan**. Prepared by the Centre for Sustainable Medicine at the National University of Singapore and global experts and practitioners from every continent, it offers a roadmap for building health system resilience and adaptation, moving from evidence to implementation.

Drawing on a comprehensive review of the academic literature, government and UN reports, and real-world case studies from the new **Belém Health Action Library**, this Special Report provides practical steps that every health ministry, health system, and health professional can take. While it is focused on health sector adaptation, it also recognizes two critical interdependencies: that these efforts will ultimately be unsuccessful without urgent mitigation; and that health ministries depend on the engagement, support, and collaboration of every sector, and every part of society.

Six central conclusions for health policy-makers and practitioners emerge from this extensive evidence base.

1. **Flexibility is the foundation of resilience.** Climate risk is dynamic, compounding, and uncertain. Today, only 15% of health organizations globally deploy forward-looking, climate-ready building codes for new construction. At its core, climate change requires health systems to look beyond traditional time horizons, plan across sectors, and change faster than they historically have. Systems must develop the institutional capacity, physical infrastructure, and financial mechanisms to remain flexible, avoid path-dependency and lock-in, and make dynamic choices that strengthen resilience over decades, not simply through to the end of the financial year.

2. **There is now more than enough evidence to act at scale, today.** Cost-effective, high-impact, and no-regret interventions exist for each component of the Belém Health Action Plan. Country-level health adaptation planning has been undertaken by 116 WHO Member States. Translating strategy into delivery now requires specialized institutional architecture. Progress is contingent on establishing dedicated Climate and Health Units within ministries to drive implementation, robust cross-government coordination mechanisms and formalized accountability to ensure health is prioritized across all sectors, and the Means of Implementation to enable this.

3. **There can be no climate resilience without health equity.** Adaptation strategies will ultimately fail unless they address the root causes of health inequity – both within health systems and across society. Of the 1,682 adaptation studies (511 focused on the health sector) reviewed in one systematic analysis, alarmingly few explicitly considered older populations

Photo by Marc Baker, Carbon Tanzania

(8%), migrants (4%), racial and ethnic minorities (4%), and people with disabilities (1%). Addressing this imbalance requires tackling poverty and the broader social determinants of health, building equity into all dimensions of adaptation planning, and moving from mere consultation to genuine codesign.

4. **Effective adaptation requires investment in the architecture that evaluates interventions.** Despite recent progress, the field is dominated by descriptive case studies, theoretical frameworks and modelling studies, with no formal tracking or evaluation in place for over 60% of National Adaptation Plans. Guiding robust interventions requires a common taxonomy, shared standards for assessing effectiveness and cost-effectiveness, a focus on local context and scalability, and sustained investment in building up the climate change and health analytical capacity of national institutions.

5. **A step-change in resource mobilization is required to meet the health adaptation finance gap.** Direct health sector adaptation interventions will require over US$ 22 billion per year by 2035, approximately 7% of total adaptation financing needs in climate-vulnerable countries and emerging economies. At COP28, the Green Climate Fund, the Asian Development Bank, the Rockefeller Foundation, and Wellcome committed over US$ 1 billion in funding, and actors ranging from the Asian Infrastructure Investment Bank to the UK Foreign, Commonwealth, and Development Office are expanding their engagement. Despite this, health sector adaptation funding need is an order of magnitude higher than existing flows, with a step-change in approach needed to deliver the Belém Health Action Plan.

6. **The evidence is clear: urgent and sustained mitigation across all sectors is the single most important health adaptation intervention.** There are profound physical, financial, and technological limits to adaptation, and health systems cannot remain resilient in a world of unchecked warming. The Belém Health Action Plan is therefore inextricably linked to the goals of the Paris Agreement and to rapid decarbonization across all sectors of the economy. Actions to reduce emissions within the health sector often generate significant operational savings that can be directly reinvested into adaptation priorities.

The path from evidence to implementation now depends on political commitment and collective will. In the face of a trying international political context, a growing global movement is bringing renewed energy to this imperative. This is seen in everything from the community building of the Global Climate and Health Alliance and the new regional capacity being deployed through the Lancet Countdown, to the political momentum built by the Alliance for Transformative Action on Climate and Health. Throughout Brazil's Presidency and beyond, the same team that produced this report will continue to review the evidence and assess progress, looking to accelerate solutions and advance the adaptation agenda through to the next global stocktake in 2028.

The interventions outlined in this report are not theoretical; they are implementation-ready and demonstrably effective. The cost of inaction will be counted in escalating disease burdens, economic losses, and irreversible harm; the benefits of action will be felt across generations.

Health is where the climate crisis becomes real – and where the solutions begin.

Introduction: Evidence for action

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> **WHO and The Lancet agree: Climate change presents the most significant threat to human health of this century.**

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With global average temperatures rising over 1.5 °C above the preindustrial average in 2024, WHO and The Lancet agree: climate change presents the most significant threat to human health of this century (1–3). This temperature rise and growing vulnerability now sees over 540 000 deaths per year from heat-related illness, a 63% rise since the 1990s (4). The health systems that serve these patients are just as vulnerable, with a recent global assessment concluding that 1 in 12 of the world’s 200 000 hospitals will be at high or partial risk of total shutdown due to extreme events under a high-emissions scenario (5). More than 70% of these hospitals are found in low- and middle-income countries (LMICs) (5).

Health systems and the health profession have responded to this challenge. In 2021, WHO launched the Alliance on Transformative Action on Climate and Health (ATACH), with more than 100 ministries of health committing to national decarbonization, to resilience efforts, or both (6). That same year, the scientific community – represented by more than 200 medical journals, ranging from The British Medical Journal (BMJ) and the New England Journal of Medicine to the Chinese Science Bulletin and the National Medical Journal of India – published a joint editorial on the health response to climate change (7). In 2023, this political and scientific commitment was reinforced financially, with more than US$ 1 billion in funding from the Green Climate Fund (GCF), the Asian Development Bank (ADB), the Rockefeller Foundation, and Wellcome (8). In 2025, the International Court of Justice (ICJ) published its advisory opinion on the “Obligations of States in respect of Climate Change”, the Global Climate and Health Alliance (GCHA) brought together organizations representing over 12 million health professionals in a global campaign, the Lancet Countdown begun a new and expanded phase of work focused on regional capacity building, and the WHO 14th General Programme of Work (GPW) and Global Action Plan provided a forward-looking legal and strategic framework for the community (4,9–12).

The Belém Health Action Plan (the Plan) builds on these political, scientific, financial and strategic foundations and offers a unified roadmap forward for health system resilience and adaptation (Box 1) (13).

This COP30 Special Report on Health and Climate Change forms part of the Plan's release, hence mirroring its structure, with a focus on the intersection of implementation and evidence. The opening section on health equity and climate justice is carried forward throughout the report. Sections 3–5 integrate the Action Lines of the Plan with the WHO Operational Framework for Building Climate Resilient and Low Carbon Health Systems, examining the scientific underpinnings and real-world interventions in: 1) health information systems; 2) capability and capacity related to health infrastructure, workforce, governance and finances; and finally 3) innovation, research and monitoring (14). The report concludes with an in-depth examination of the profound limits to adaptation, the consequences of unmitigated climate change, the synergies between resilient and low-carbon strategies, and the resulting need for a balanced and strategic global approach.

Box 1

The Belém Health Action Plan and the COP30 Special Reports

The Belém Health Action Plan is grounded in the COP30 Presidency's broader Action Agenda (15). Six Thematic Axes and 30 Key Objectives of the Action Agenda address each of the dimensions of action on climate change. These include: the energy transition; stewarding biodiversity; transforming agriculture and food systems; building resilient infrastructure; fostering human development; and accelerating finance, technology, and capacity building. Objective 16 under Pillar 5 of the Action Agenda focuses on "Promoting Resilient Health Systems" and provides the framework and context for the Belém Health Action Plan.

A broad consultative process began as soon as Brazil took on the role of COP President, culminating in a draft text presented at the 2025 Global Conference on Climate Change and Health in Brasília. The Plan's core Action Lines offer an overarching objective and several Sub-Action Lines, highlighting areas of focus for countries and health systems to pursue while strengthening health system resilience (13).

Two Special Reports accompany the Plan to help advance action towards climate-resilient health systems. The work of this report was overseen by an Expert Advisory Group, convened by the Brazilian Ministry of Health. Drawing on academic literature, government and UN agency reports, and numerous examples of action from the health community across the world, it focuses on moving from evidence into implementation, providing practical recommendations for cross-sectoral action at the ministerial and institutional levels.

At the same time, it launches the Belém Health Action Library (BHAL) highlighting innovative and impactful examples of health system resilience from across the world. Throughout this report, a parallel referencing system is used to bring this evidence to life, denoted by "**BHAL ##**" with a corresponding textbox linking to the full case study online (available at www.atachcommunity.com/bhal) (16).

This report's sister publication on social participation takes forward the focus on social participation and representative leadership and governance.

Importantly, this work must be understood within the broader context of the health and climate change community. Although its focus is on adaptation and resilience in the health sector, progress rests on two clear interdependencies. First, action from health and healthcare alone is insufficient; coordinated efforts across all sectors – from agriculture to sanitation – are required. Second, without rapid decarbonization, no amount of funding or political commitment to adaptation will be enough to protect the health of patients and the public. This Special Report addresses both interdependencies while maintaining its focus on moving from evidence to implementation in support of the Belém Health Action Plan.

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Photo by Patrick Hans Mulindwa

1.1 Health in a changing climate

No country and no community is immune to the health impacts of climate change, with 3.3–3.6 billion people currently living in high climate-vulnerability contexts (17). Temperature rise and extremes of heat place direct strain on the renal and cardiovascular systems of millions of people (18,19). These health consequences make economically productive work harder, with the Lancet Countdown estimating some US$ 1.09 trillion (just under 1% of global GDP) was lost in 2024 as a result of reduced labour capacity (4). More intense and more frequent storms cause direct injuries, disrupt critical infrastructure and sanitation systems, and exacerbate existing mental ill-health (20). Compared to 1990, hospitals and health facilities are already experiencing a 41% increase in the risk of damage from extreme weather events due to climate change (5). Freshwater and food systems are also affected, with rates of severe stunting from malnutrition in children under five projected to increase by 23% and 62% in sub-Saharan Africa and South Asia, respectively (21). The underlying drivers of climate change are responsible for more than 5 million premature deaths each year from fossil fuel-related air pollution (more than 6.7 million from all sources), and are just as concerning as the downstream impacts that could see an additional 132 million people in extreme poverty by the end of the decade (22–24).

While ongoing work is always required (for example, to provide improved spatiotemporal resolution of climatic change or population vulnerability, or to understand the consequences of multiple correlated impacts), the health impacts of climate change are well defined (Fig. 1).

In reviewing the literature and the case studies submitted to the Belém Health Action Library, one core conclusion stands out. Despite the numerous adaptation interventions available to protect the health of patients, the public and health systems, they each have critical technological, financial or social limits (25,26). These limits to adaptation are such that often the most important starting question for any intervention is, “what world and what degree of warming are we adapting to?” The capacity and investment required for an adaptation intervention in a 1.55 °C world is fundamentally different to that required in a 2.7 °C world (current policy consensus), or even a 4.4 °C world (seen in SSP5–RCP8.5, in the event of active policy backsliding) (27–29). The link is clear and inextricable. Health system adaptation cannot be successful without rapid and urgent fossil fuel phase-out, and decarbonization across all sectors of the economy and all parts of society.

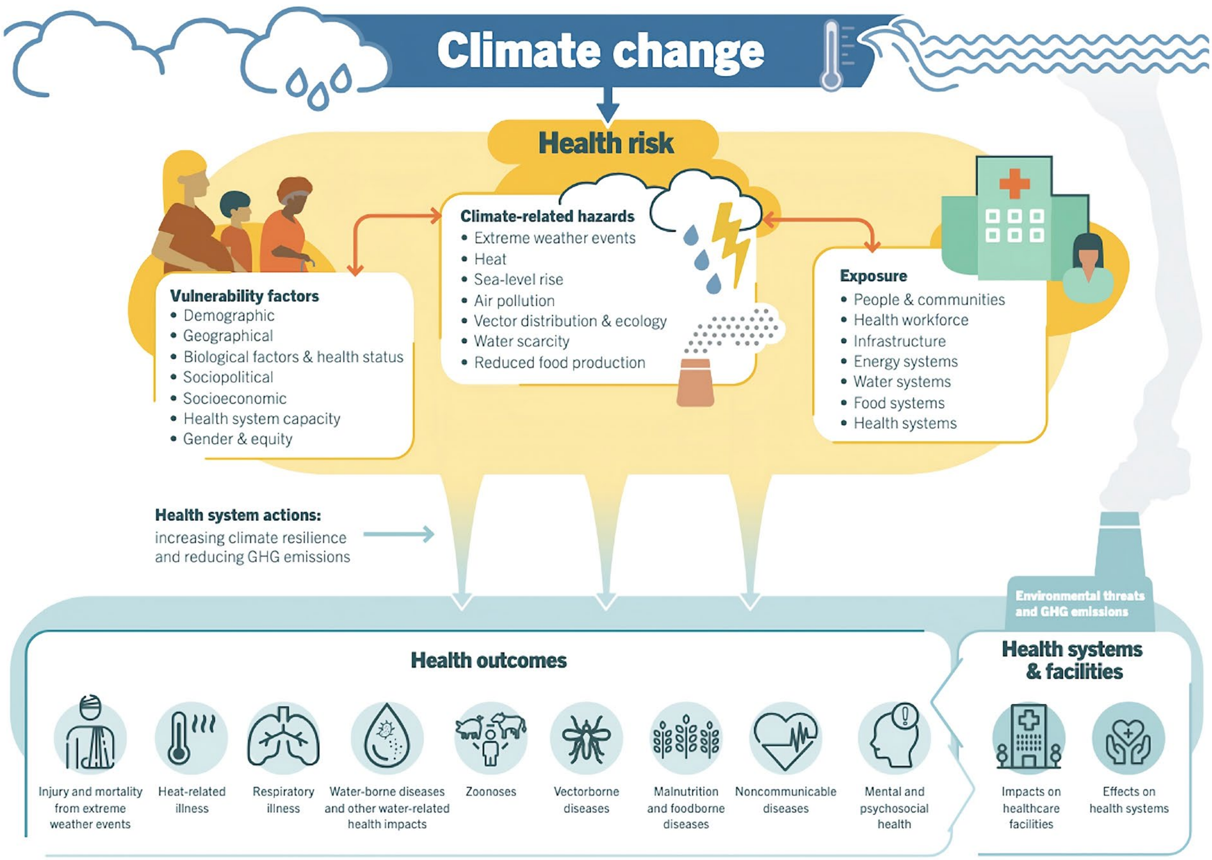

Fig. 1: The impacts of climate change on human health (14).

1.2 Health system resilience and adaptation

Three conceptual frameworks from WHO are useful in introducing the role of health systems in adaptation: the Social Determinants of Health; the six health system building blocks; and the Operational Framework for Building Climate Resilient and Low Carbon Health Systems (14,30,31).

The Social Determinants of Health framework makes clear that the foundations for good health are underpinned by everything from access to healthy food, water and sanitation, through to stable housing, social networks and valued work (30).[BHAL 25] This dependency on nearly every other sector and every other part of society creates profound vulnerabilities for health, with clinical care itself often estimated as being able to influence only 10–20% of variation in premature mortality (32). Health adaptation cannot occur in isolation and must, by definition, be supported by all of the health-determining sectors and placed in context of rapid and profound changes in both economic development and climate change (33).[BHAL 39]

BHAL 25: Building resilient, safer communities together

BHAL 39: Harvesting rain to secure rural futures

Correspondingly, the six building blocks of a health system framework (seen in the inner ring of Fig. 2) focuses attention on the formal health sector, and identifies levers and mechanisms commonly within the direct operational control of a ministry of health. The 2023 WHO Operational Framework (Fig. 2) builds on both of these concepts, defining the intervention space for action on climate change from health systems and other health-defining sectors (14).

The Belém Health Action Plan and the Operational Framework engage with the distinct, but related, concepts of adaptation and resilience. The adaptation elements focus on the process of adjusting and ensuring flexible systems, policies, and practices to specific climate vulnerabilities, exposures, hazards, and ultimately, risks. Resilience is concerned with the ability of a health system to withstand shocks while continuing to function under stress, recover quickly and even emerge stronger (34).

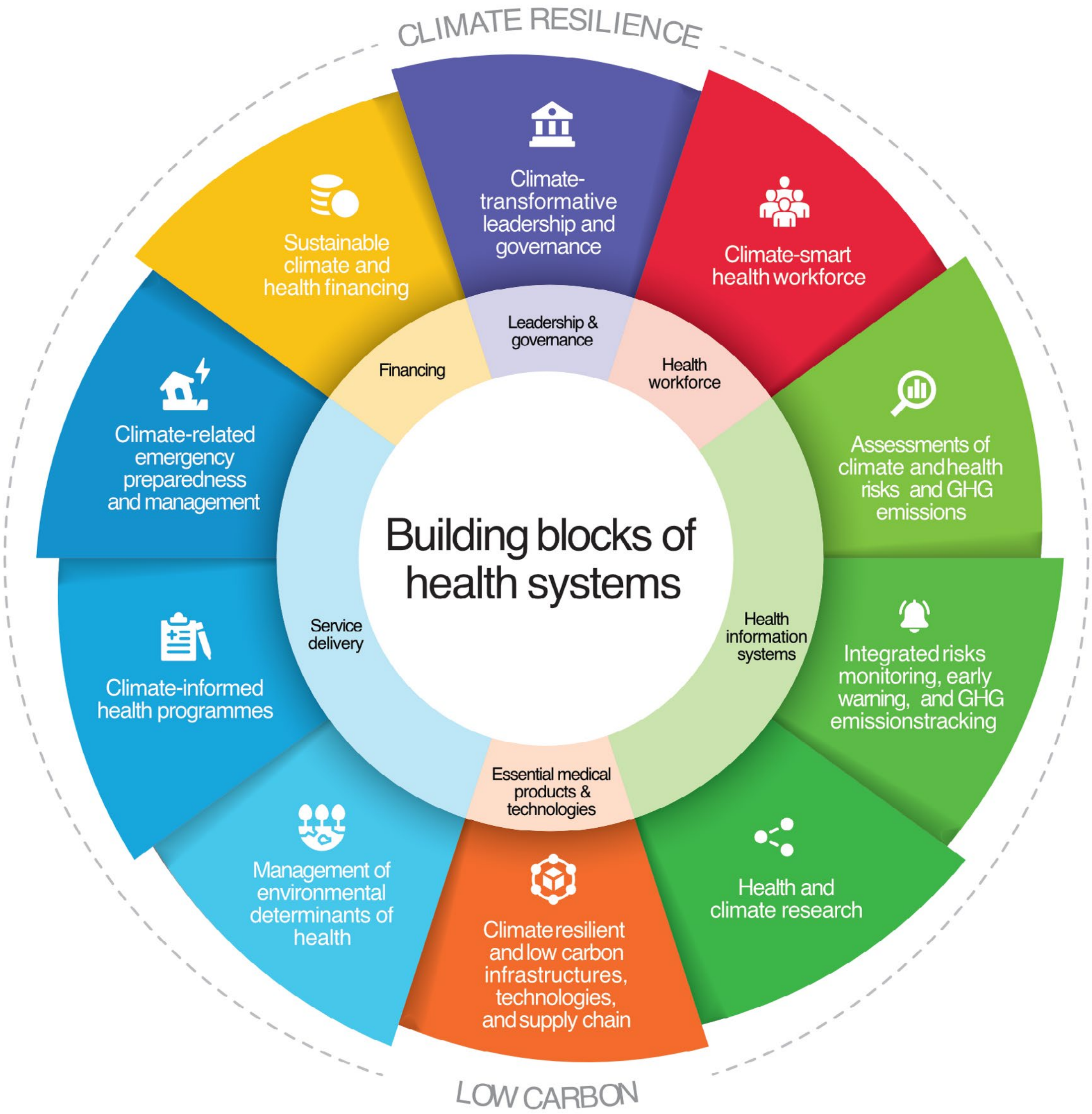

Fig. 2: The WHO Operational Framework for Building Climate Resilient and Low Carbon Health Systems (14).

1.3 Progress, process and perseverance

The world has changed significantly since the inception of the UN Framework Convention on Climate Change (UNFCCC) at the 1992 Rio Earth Summit and the development of early academic literature on human health and global environmental change (35). The global population has risen by approximately 50% from 5.5 billion to over 8.2 billion people, associated with a dramatic change in consumption patterns and a corresponding 58% increase in greenhouse gas emissions, to 54.1 billion tonnes CO_2e (36,37). At the same time, the total number of people living in extreme poverty has decreased dramatically from 2.3 billion people (34.3% of global population) to 0.8 billion (10.0%), and global average life expectancy has increased by almost 10 years (38).

Similarly, the health community has made significant progress within the UNFCCC process since its early involvement as a thematic area in the 2005 Nairobi Work Programme and as an opening justification for the 2015 Paris Agreement (39,40). In 2021, COP26 saw the formation of a new alliance of health ministries (ATACH) committed to developing low-carbon and resilient health systems. Each subsequent year has brought renewed enthusiasm for the health dimensions of Loss and Damage (COP27, Egypt), financing (COP28, UAE), the health argument for climate action (COP29, Azerbaijan), and a wider arc of progress centred on the Global Goal on Adaptation (GGA) (41–43). The growing momentum at the international level is reflective of two shifts. First, the health community's presence in the UNFCCC process has grown from only a handful in the early 1990s to well into the thousands in the 2020s, with 53 national health ministers attending COP28 in Dubai (44). Second, it reflects a genuine rise in action from the health community at both the national and local levels.

To date, 90 countries have committed to developing climate-resilient health systems at the ministerial level, and a total of 58% of all WHO Member States have conducted a vulnerability and adaptation (V&A) assessment (4,45). These assessments are a good indication of strategic planning and action, with the Lancet Countdown estimating that over 116 Member States (60.1%) reporting the completion of a Health National Adaptation Plan (HNAP), and 32% of ATACH members having completed or updated their HNAP since 2020 (4).[BHAL 62]

These strategies quickly translate into tangible action that can then be evaluated. In 2025, the World Bank, KfW Development Bank and the Inter-American Development Bank reviewed a wide range of available health sector adaptation interventions from across the world, conducting value analyses on those that had been evaluated and shown to be effective, identifying eight high-value actions (Box 2) (46).

BHAL 62: Integrating health into Iraq's national adaptation

Box 2

Smart Buys: High-Value Actions for Health Sector Adaptation (46)

Value analyses of a wide range of case studies have been conducted with a focus on measurable health outcomes, scalability, and economic value. While these represent individual studies in specific contexts, economic evaluation of all eight actions demonstrated that benefits exceeded costs, and the examples are indicative of interventions to be considered and applied in new settings.

1. **Caribbean (7 countries) – Climate resilient health infrastructure: SMART Hospitals retrofits.** Safe and green upgrades kept facilities functioning through hurricanes and eruptions while lowering operating costs. Retrofitted sites served 850,000 people and maintained service continuity during disasters.

2. **Africa (modelled; Rwanda, Ghana, DRC) – Drone-based medical supply chain delivery.** On-demand drone networks cut delivery times, reduced wastage, and improved availability of time-sensitive commodities. Results show large health and economic gains that grow sharply with scale.

3. **Ahmedabad, India – Implemented Heat Action Plan (HAP).** A health-led, cross-sector plan with alert thresholds, public guidance, and preparedness averted an estimated 2,380 deaths over two years. The low-cost programme (early warning, communication, capacity building, adaptive measures) offers a replicable model for urban heat resilience. BHAL 38

4. **Alberta and Nova Scotia, Canada – Text-based telehealth services: Text4Hope mental health support programme**. Daily cognitive behavioural therapy -informed texts during wildfire displacement provided rapid, low-cost mental health support. Evaluations found reductions in depression, anxiety, and post-traumatic stress disorder, with very low per-user costs and strong scalability.

5. **Anambra State, Nigeria – Mental health services: Specialist-led Rational Emotive Family Health Therapy.** Manualized, group-based therapy for flood-affected farmers reduced anxiety with effects maintained at follow-up. Integration into primary care can expand reach and sustain quality.

6. **Karachi, Pakistan – Community Health Worker-led education: Heat and Emergency Education (HEAT).** Trained workers delivered household-level education on heat risks and prevention, improving knowledge and behaviours. A randomized trial showed a 38% reduction in all-cause hospitalization and substantial avoided household expenditures. (47)

7. **Hong Kong SAR – Integrated surveillance and early warning and response systems: Air Quality Health Index (AQHI)**. The index provides timely, actionable air-pollution alerts with tailored guidance for high-risk groups, integrating monitoring, communication, and response. Hourly updates helped reduce hospital admissions for respiratory and cardiovascular diseases, preventing over 5,700 admissions in three years and yielding an estimated net-present value of about US$ 250 million.

8. **Brazil, Colombia, Mexico, Malaysia, Philippines, Thailand – Mosquito vector control: Sustained vector control for dengue.** Integrated, high-efficacy monthly control reduced transmission across seasons and outbreaks, averting illness and health costs and controlling mosquito-borne diseases. BHAL 32

BHAL 38: Saving lives through heat-health action planning

BHAL 32: Coordinating data-driven dengue control

Principle 1

Health equity and climate justice

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Recommendations

1. **Without addressing the root causes of health inequity, even the strongest adaptation efforts will ultimately fail**

   The social injustice that drives health inequity within and between countries is pervasive Adaptation strategies must be paired with structural reforms that tackle poverty and address historical inequalities. Only by tackling these determinants can climate adaptation deliver sustained and equitable resilience.

2. **Health adaptation planning must move from community consultation to co-design**

   Codesign and participatory approaches that actively seek input from socially, politically, and economically marginalized communities to augment all forms of adaptation and resilience are essential. There is good evidence demonstrating that programmes designed with these marginalized populations are more responsive, trusted, and effective in strengthening resilience.

3. **Disaggregate data to guide fairer adaptation**

   The interventions in each subsequent section – from health information systems to workforce planning and financing – rely on sound data to be effective. Ensuring all countries have the means of implementation needed to expand monitoring and population health datasets to greater levels of disaggregation will provide the justification and evidence base to address underlying health inequities. Evaluation should be built into implementation of climate adaptation interventions to assess cost–effectiveness, facilitators for and barriers to impact, and to minimize trade-offs.

2.1 Introduction

Health inequities are intensifying as climate change intensifies. Between 3.3 and 3.6 billion people already live in low- and lower-middle-income contexts highly vulnerable to climate hazards, where weak health systems and limited adaptive capacity amplify risk (17,48). Over the past two decades, more than 90% of deaths from climate-related disasters occurred in these settings (49). This must be understood in a context of climate injustice, where these same 3.6 billion people (nearly 50% of the global population) generate less than 10% of global emissions (50).

Equity cuts across the entire hazard-exposure-vulnerability risk framework (51). The hazard itself – though directly a physical phenomenon, such as a flood or a heatwave – reveals deep underlying inequalities, with those who had nothing to do with climate change still affected by it. Exposure reflects who is placed in harm’s way: those with fewer resources are more likely to live or work in high-risk environments, from informal coastal settlements to agricultural fields without adequate protection. Finally, vulnerability captures the capacity to anticipate, cope with, and recover from impacts, and is profoundly shaped by access to healthcare, education, housing, infrastructure and social protection.

The underlying drivers of climate-related health inequities are rooted in historic and ongoing patterns of economic and political marginalization that have seen resource, power, and emissions concentrated in one place, while the impacts are externalized elsewhere (52). Many of the structural determinants of health that result from this, including access to land and housing, education, decent work, energy and stable governance, can be influenced by the health sector, but often lie beyond its direct reach (30). Achieving climate justice therefore depends on addressing the historical and underlying inequities, and transforming a broad array of systems and sectors across society (53). Acknowledging this, what follows is focused on the health sector – on the actions required within health systems to protect populations, redress inequities and build resilience. While the determinants of inequality extend far beyond health ministries, the sector remains a critical lever: both as a first responder to the human consequences of climate change and as an advocate for cross-sectoral action that places health equity at the centre of climate policy.

2.2 Health equity across the building blocks of a health system

Climate justice is a highly contextual concept, varying significantly across settings and applications (54). In appreciation of these contextual nuances, the literature and this report do not adhere to one single definition of climate justice.[BHAL 52] Rather, decision-makers are encouraged to identify locally relevant definitions, and to be explicit about how climate justice is being conceptualized and operationalized in all programmes (54,55).

A systematic review of peer-reviewed empirical papers on human adaptation considered the equity dimensions of the findings from some 1,682 papers (56). It found equity considerations were actively considered in 52% of planning and 59% of reviewed implementation papers (Fig. 3). In articles focused on health adaptation, less than 30% considered income status, approximately 20% considered gender, and less than 1% focused on people with disabilities.

BHAL 52: Addressing equity and justice in Timor-Leste

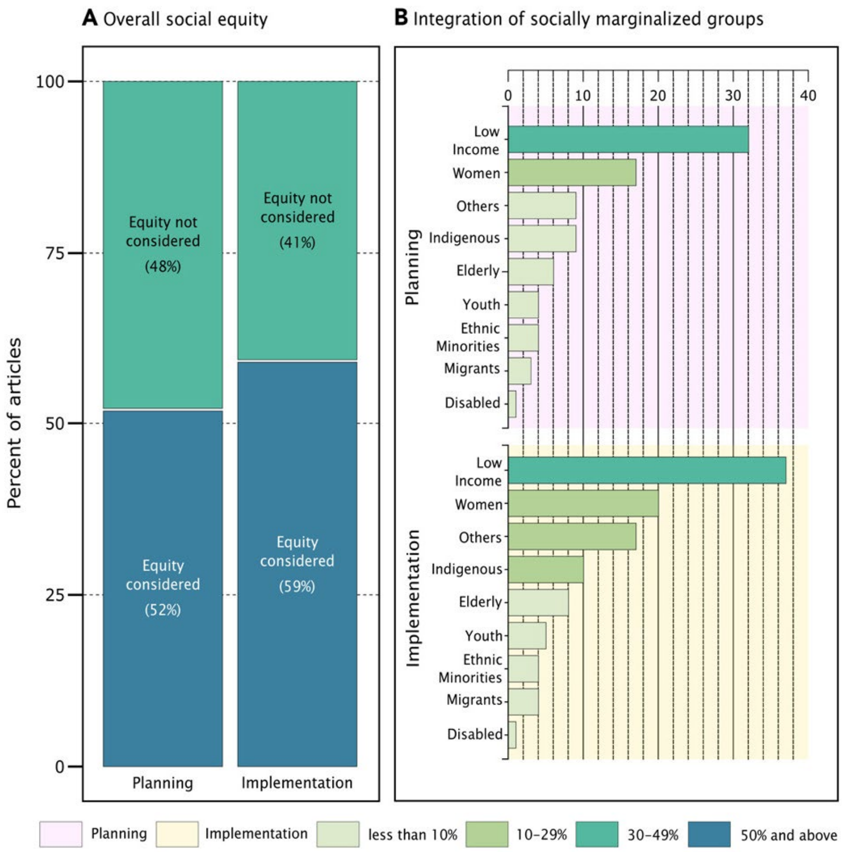


Fig. 3a: Percentage of overall articles that include or omit equity considerations.
Fig. 3b: Percentage of overall articles that integrate different socially marginalized groups into adaptation (counts are not mutually exclusive) (56).

This subsection examines the integration of health equity into the design, implementation, and monitoring of each of the six building blocks of a health system (14). Inherent in the nature of the issue, there is currently a paucity of evidence available for review at the intersection of climate change, health adaptation and equity. Consequently, what follows draws heavily on adjacent bodies of literature, including work on the social determinants of health, race and health, and climate justice.

2.3 Leadership, governance and finance

Ultimately, leadership and governance are at the heart of the integration of equity and climate justice into health adaptation, determining how power is distributed, whose interests are prioritized and which voices shape decisions. Evidence across contexts points to three key governance strategies.

First, new equity metrics and indicators embedded within existing climate and health programmes and governance processes that strengthen accountability and transparency. Second, legal and regulatory requirements that integrate equity into social, environmental and health impact assessments, creating formal entry points for consultation and codesign.[BHAL 63] Third, cross-ministerial coordination mechanisms that enhance government capacity to deliver equitable and holistic adaptation strategies across all sectors.

Despite this evidence, implementation is often lacking, because the means of implementation are often lacking (57). Integration is hindered by structural barriers: limited financing, fragmented data systems, siloed communication and unclear accountability. Marginalized groups including women, Indigenous Peoples, migrants and persons with disabilities are often excluded from policy discussions that inevitably shape their vulnerability to climate change (58,59). Such exclusion can lead to policies and interventions that do not reflect their needs and priorities (60). Section 4.4 discusses how equitable progress on climate and health adaptation is constrained by two systemic financing inequities.

The first is straightforward to name, and difficult to address – the global pool of available funding is simply insufficient. Between 2018 and 2022, US$ 7.1 billion of funding was committed to the intersection of climate change and health(61). While estimates vary, and this represents an increase in available funding, it remains the case that only 2% of climate adaptation funding and 0.5% of multilateral climate funding is allocated to projects that directly protect or improve human health (62). This must be taken in the context of the global health cost of air pollution (US$ 8.1 trillion in 2019) and explicit and implicit global subsidies provided to the fossil fuel industries that cause this health burden (US$ 7 trillion in 2022) (63,64).

BHAL 63: Empowering Indonesian villages for climate-health resilience

Photo by Eyoel Kahssay on Unsplash

The second inequity concerns access and allocation. Even when resources exist, it is often difficult to ensure they reach the populations most in need. Strict eligibility criteria, complex reporting and application requirements, and cofinancing stipulations can disadvantage those in the least-resourced settings (65,66).

2.4 Health workforce

Health workforce capacity remains heavily concentrated in high income countries, with 47% of capacity concentrated in countries with only one fifth of the total world population (67). Climate change places greater strain on health services, exacerbating existing workforce shortages, particularly in already vulnerable low-resource settings (68). Climate change can also reshape where health workers are needed most, yet patterns of workforce deployment remain uneven, with persistent shortages in rural, remote and underserved areas worldwide (69). These service gaps are further compounded by the direct impact of climate change on health professionals themselves. Adaptive workforce planning must therefore focus on retention and equitable distribution, and be supported by incentives, training and safe working conditions that allow staff to remain in high-risk settings. Protecting health workers from occupational hazards – heat exposure, infectious disease, mental stress and infrastructure failure – is both an issue of equity, and a prerequisite for sustained service delivery (69–71).

Beyond ensuring adequate workforce capacity within and between countries, the capabilities needed to address health inequities are also critical. Building competence in climate and health equity through undergraduate and continuing education for frontline providers and health policy-makers improves service responsiveness and cultural safety in care (72). Equally, healthcare workers bring their own personal and professional experiences with the impacts of climate change that can enhance service delivery.[BHAL 57] Such knowledge can be investigated and incorporated into health workforce training on climate change, health, and health equity.

BHAL 57: Resilience through equitable adaptation in Pakistan

2.5 Health information systems

Four key dimensions of equity and health information systems stand out in the adaptation literature and can be expressed as individual questions: who is represented in the data (*visibility*); whose frameworks shape analysis (*interpretation*); who can access and act on the data (*use*); and which forms of knowledge are legitimized or excluded (*knowledge pluralism*).

Health information systems are the foundation for understanding and addressing climate-related health risks, yet the data contained within them often fails to capture those most affected (73,74). Expanding monitoring and surveillance systems' ability to collect granular data on the impacts of climate change across vulnerabilities is the most obvious and most frequently overlooked first step (75,76).[BHAL 44] Increasingly, it is possible to attribute health outcomes to human-induced climate change. Although publications undertaking such analyses are currently few in number, they will increase markedly in future with important implications for designing and evaluating adaptation programmes and for climate litigation (77). Guidance on undertaking such analysis is available to support consistent and rigorous approaches to attribution research (78).

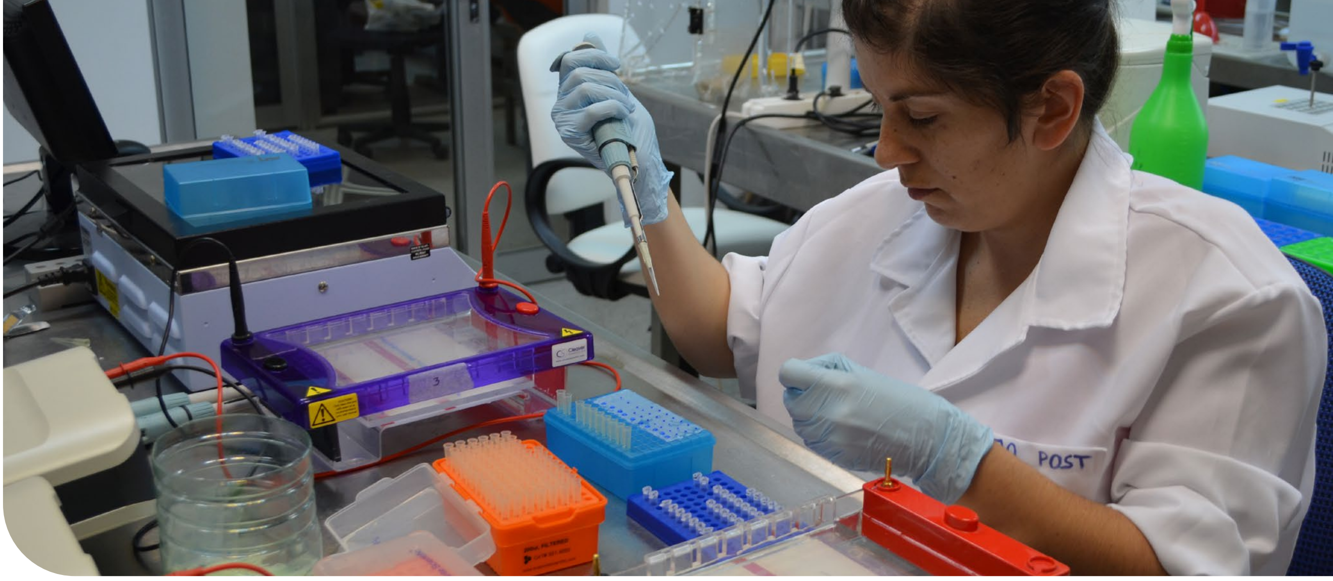
Having established equitable data collection and governance measures, the interpretation of health information is the next important tool in addressing equity considerations. While the scientific and grey literature frequently discusses gender, socioeconomic status and age, there is a clear and pervasive gap with respect to ethnicity, Indigenous communities, people with disabilities (PWDs) and LGBTQIA+ communities (56). Beyond individual characteristics, intersecting forms of vulnerability and marginalization are clearly important. The literature tends to engage with a few specific forms in groups: older and younger people are often jointly considered, as are PWDs and older people (56).

Finally, equity in climate adaptation relies on plural knowledge systems (79). Incorporating Indigenous knowledge and people with lived experience expands what counts as evidence, providing access to a significantly broader wealth of expertise and evidence (80). This actively works against a legacy of exclusion that risks undermining the effectiveness of climate and health policies.[BHAL 5 & BHAL 22] Without it, the evidence base guiding adaptation will remain incomplete and may perpetuate the very inequities it aims to resolve.

BHAL 44: Designing safer, inclusive disaster planning

BHAL 5: Bridging science and indigenous knowledge for resilience

BHAL 22: Healing people and forests through radical listening



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2.6 Essential medical products, technologies and supply chains

Access and affordability, the appropriateness of technology for different geographies and income settings, and supply chain resilience each bring important equity dimensions and interventions when addressing the fourth WHO building block of health services (14).

Advances in digital and remote medicine bring the ability to leapfrog traditional barriers to care (81). Telemedicine platforms and mobile diagnostics can extend specialist services to remote areas, enable coordinated screening programmes without the need for extensive physical infrastructure, and deliver care closer to home (82). By reducing travel burdens, lowering costs and increasing continuity of care, these innovations hold the potential to narrow existing health inequities (83). However, without careful design, they may also risk exacerbating disparities if connectivity, affordability, or digital literacy are unequally distributed. Globally, 72% of urban residents have internet access compared with only 38% in rural areas, with a total of 2.9 billion people offline in 2020 and less than 30% of people in Least Developed Countries using the internet (83,84). Addressing this risk requires combined investment in connectivity and digital literacy, with the continued use of low-tech and offline solutions such as SMS alerts and radio networks. Designing technologies with accessibility across languages, literacy levels and disability statuses ensures that digital transformation strengthens, rather than fragments, equity. In Nepal, the MANTRA (Maternal and Neonatal Technologies in Rural Areas) project successfully improved women's literacy of various hazards by gamifying the digital literacy education process, mapping 28 learning objectives focused on climate hazards, health seeking behaviour, and maternal and neonatal well-being (85).

Used correctly, health service supply chains and procurement systems can be critical drivers of community development and equity (86). Health systems will be among the largest employers and purchasers in any economy – from a global city to a local rural town. Accounting for more than 10% of global gross world product and with a 65-million-strong workforce, hospitals, clinics and public health agencies act as anchor institutions within their communities (67,87). They provide stable jobs, purchase goods and services locally, and build resilience in the surrounding population. Integrating social value dimensions into healthcare procurement is one particularly potent intervention seen the world over. By sourcing medicines, medical equipment, and renewable technologies from local or regional suppliers, health systems can stimulate green jobs, shorten supply chains, and build self-reliance during climate shocks (88).

2.7 Service delivery

Despite the equal weighting given to each of the building blocks, service delivery contains the elements that the majority of the population experience directly and is correspondingly where climate resilience and health equity converge most sharply. Climate change requires health systems to consider new risks across three operational settings: 1) the design of new, climate-specific programmes that address emerging risks; 2) the maintenance of core health services during and after climate shocks; and 3) coordinated action with other sectors to manage the health dimensions of water, food, energy and housing systems (14).

Achieving equity across these domains depends on the enabling conditions established through the other health system building blocks. For example, disaggregated data is essential to guide new health programmes and protect vulnerable populations in the event of an emergency.[BHAL 19] Equally, a health workforce with the skills and capacity needed to deliver care in remote areas under stress will ensure service continuity. Primary care is often responsible for an individual's first point of contact within a health system, meaning that the primary health workforce are well placed to identify vulnerable populations and individuals for priority interventions and provide early warning of climate hazards (89).

BHAL 19: Cooling care with low-carbon innovation

2.8 Conclusion

Tackling health inequity requires a systems approach, one that seeks to achieve transformative justice and ensure long-term protections for the health of those most vulnerable to the impacts of climate change. Although the actions presented in this section are thematically contained, there is great interconnectedness between them. Ultimately, the pursuit of health equity in climate action must confront questions about the fundamental ways in which resources are distributed, whose experience and expertise is valued in knowledge-production processes, and the political and social norms that perpetuate and often exacerbate existing inequality.

Action Line 1

Health information systems

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Recommendations

1. **Prioritize interoperable, climate-informed, and future-ready health information systems**

   Integrated environmental, meteorological, and health datasets are the cornerstone of every health adaptation strategy. They require sustained long-term effort, formal partnerships, and data-sharing arrangements across ministries and agencies that ensure data can move to where the needs are greatest. Critically, these information systems must be oriented towards addressing risks from both current and future climate change, and aligned internationally to support regionally and globally integrated monitoring.

2. **Invest in analytic capacity and data governance**

   Health adaptation requires new skills and capabilities that are not traditionally held within a health ministry. While partnership with external organizations is helpful in the initial stages, effective interventions will ultimately require dedicated in-house analytical capacity.[BHAL 17] Ensuring all countries have the financial resource and capacity to develop these systems is essential.

3. **Ensure all parts of the population are visible**

   Focus data collection and investment on the populations most vulnerable to climate change. Where resources permit, disaggregate data by income, gender, age, disability, geography, and any other relevant population group to reveal who is most exposed and least protected. Integrating these metrics into surveillance and early-warning infrastructure turns data from an analytical tool into a mechanism for accountability and fair resource allocation.

BHAL 17: Setting global standards for climate-health data

3.1 Introduction

The first Action Line of the Belém Health Action Plan focuses on surveillance, monitoring and health information systems (HIS) more broadly. These systems enable analysis of environmental hazards, exposure and vulnerabilities, making them the critical foundation of proactive climate adaptation in the health sector (13,90). They already exist in each country to varying degrees of maturity, providing decision support to infrastructure and workforce planning, operational clinical services, and long-term health policy (91). Establishing effective information systems requires working across inherently complex networks of institutions, government agencies, providers and clinics, often navigating fragmented data and information silos with interdependencies across sites and services. Climate change places new demands on these systems, requiring novel skills and knowledge, a renewed imperative for longer time horizons, and new partnerships.

Within the context of a changing climate, these systems serve dual purposes, supporting both immediate action in response to new threats (storms, heatwaves or the spread of infectious disease) and enabling long-term monitoring, prevention, and evaluation (92). The evidence base here is developing rapidly, though still strongly biased towards high-income country contexts, primarily due to data availability and resources. There is a risk of overreliance on routinely available metrics and data sources, which may provide minimal additional insight into the effectiveness of specific interventions (75,93).

There is limited consensus surrounding common nomenclature, detailed implementation and evaluation guidance, and understanding of how early warning systems (EWS) operate in challenging and lower-resource environments. While most of the scientific evidence is found in peer-reviewed publications, insights from grey literature, official debriefs, and post-event evaluations should not be overlooked (73).

This section takes this evidence and provides a roadmap for response centred on four categories of intervention: assessing climate and health risks; early warning systems; surveillance; and the integration climate information into long-term planning decisions. Research and innovation on climate change and health are covered in Section 5.

3.2 Assessment of climate and health risks

Multiple approaches are available to assess climate and health risks, each involving an appraisal of the potential consequences of climate change and the likelihood of those consequences occurring.[BHAL 51] The commonly used hazard-exposure-vulnerability framing is adapted below for a health adaptation context, adding a response dimension (Fig. 4) (94). A capacity assessment goes one step further, focusing on the ability of a system or population to respond to climate change impacts, including the adaptive capacity and the potential for recovery (95,96).

BHAL 51: Integrating health adaptation into UAE's national action

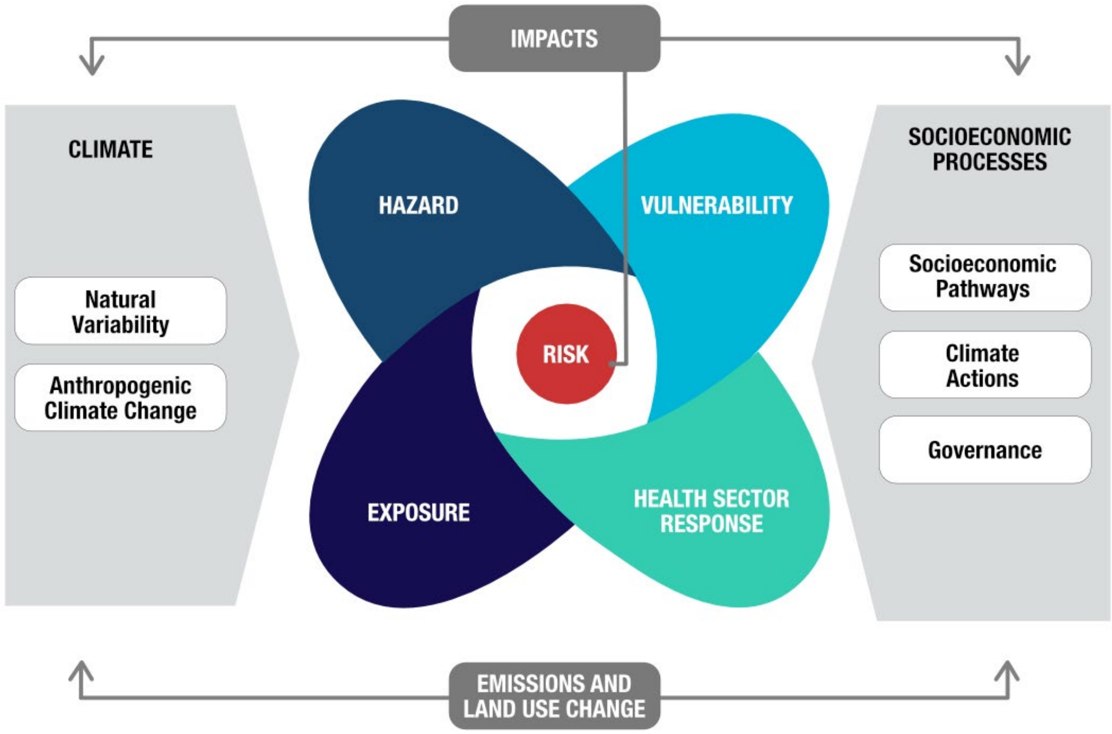

Fig. 4: Risk as a function of hazard, exposure, vulnerability, and response (adapted from Begum et al., 2022) (94).

Where national data is unavailable or incomplete, international monitoring platforms such as the Lancet Countdown are available, using regional estimates, international data and proxy metrics to provide nationally appropriate insights into decision support for countries (97).

One particularly valuable review identified 25 tools and methods for assessing health vulnerability and adaptation (V&A assessments) to climate change (98). The majority of the identified assessments were designed for high-resource settings, were at the district level or lower, and considered all the relevant climate hazards. While precise methods vary depending on the specific interests of the health system in question, Fig. 5 lays out a common approach, noting the importance of iteration and emphasizing that the first assessment is rarely comprehensive or complete (99).[BHAL 28] WHO recently examined 31 V&A assessments in greater detail, with more than three-quarters of them focusing on infectious disease and respiratory illness, extremes of heat and weather and the direct impacts on health services. At the same time, concerningly few assessed specific risks to people with disabilities (35%), migrant populations (42%), people living in poor housing (42%) and outdoor workers (52%) (100).

BHAL 28: Assessing hospital resilience in rural Chad

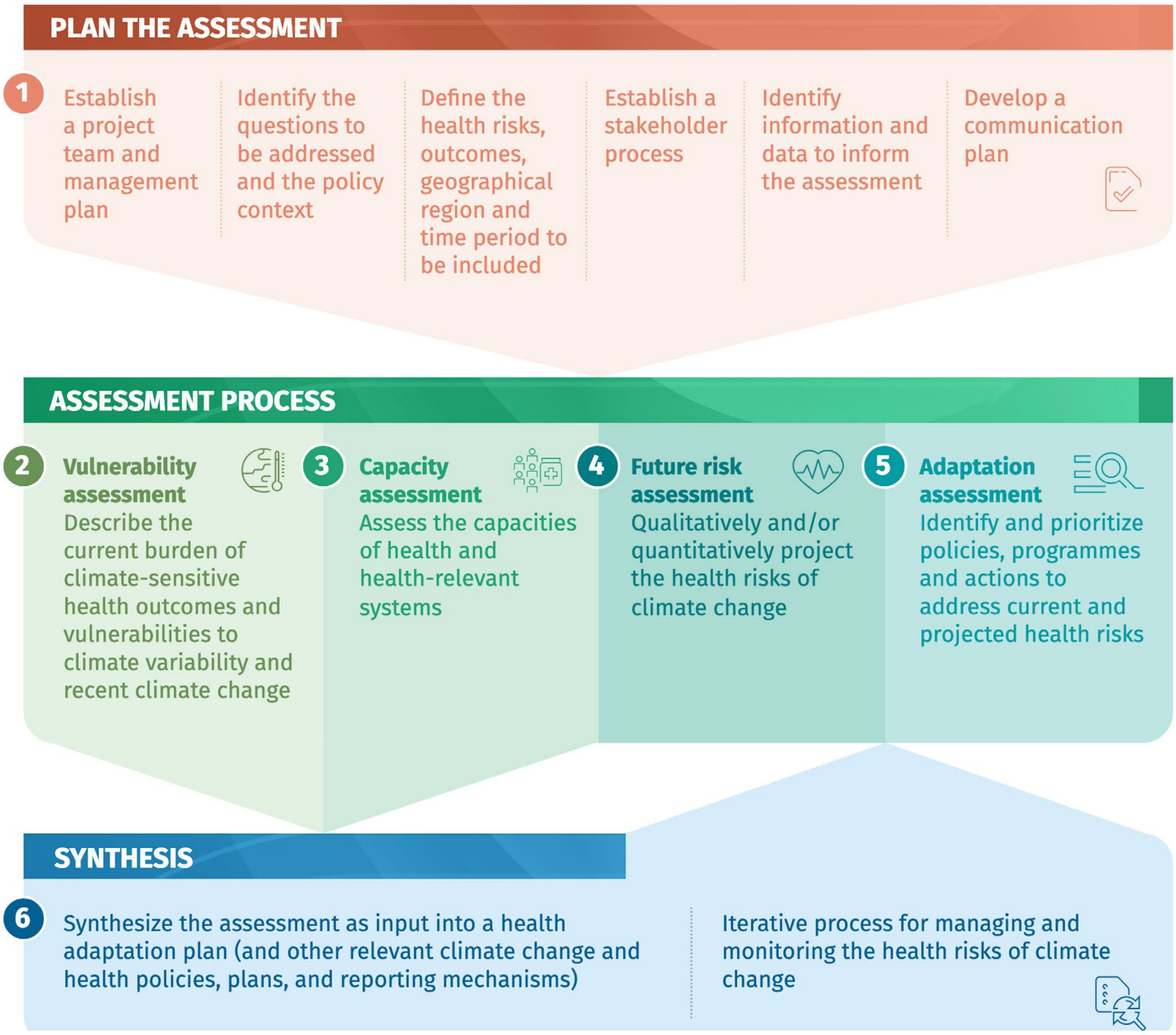

Fig. 5: A framework process for conducting a climate change and health vulnerability and adaptation assessment (99).

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In all 31 studies considered, the V&A assessment was used to underpin and inform formal climate change adaptation planning and National Adaptation Plans (NAPs).[BHAL 61] Depending on the local policy context, this takes the form either of a health component or chapter integrated into the NAP, or a standalone HNAP. As of 2025, 116 WHO Member States have completed either an HNAP or a health chapter within their NAP, though over 70% of these were conducted by Very High (39.3%) or High Human Development Index (HDI) (30.4%) countries (4). Mirroring the WHO study of V&A assessments, a review of the actions planned in a sample of 76 national strategies found that a strong majority focused on interventions related to leadership and governance (78%), developing a climate-smart health workforce (67%), and integrated risk monitoring and early warning systems (71%). However, despite this, comparatively few strategies actively engaged with the broader environmental determinants of health (28%) or had developed a strategy for sustainable climate and health financing (31%) (101).

A comprehensive risk assessment supports the identification of the nature and scale of risk across different time horizons and projections; supports the development of adaptation policies aligned with each of these; and is an important tool to raise awareness and to gather support both within and beyond government (102,103). Table 1 summarizes common approaches and key limitations encountered as health systems work to develop comprehensive assessments.

BHAL 61: Advancing resilience through national health planning

Table 1: An overview of common enabling factors and barriers in the development of high-quality V&A assessments

Common approaches associated with a high-quality V&A assessment	**Common limitations preventing high-quality V&A assessments**
1. Utilize an **established methodology** (for example, the WHO V&A Guidance, or the UK Climate Change Risk Assessment) which combines expert reviews, climate modelling and risk assessments to inform decision-making (99,104,105). BHAL 68 2. Ensure that the assessment is **consistent and integrated** across different sectors and regions, using harmonized, transparent approaches to collate and assess evidence from different sources (104). **3. Consultation and codesign** both within the health system and across all relevant sectors (104). **4. Priority assessments for at-risk groups** (e.g., older people, people with chronic diseases) and avoidance of adaptation measures that widen inequalities (104). 5. The assessment is designed specifically with the goal of **enabling adaptation planning** and strategies (106,107).	1. The development of resources and strategies that are **nonactionable, limited by unrealistic assessments of available resource** or capability (107). 2. Reliance on overly simplistic checklists that **overgeneralize and ignore local context** (107). 3. A focus only on individual, direct impacts, **failing to assess compounding or cascading risks** (e.g., healthcare disruption, mental health consequences) (108,109). 4. A **lack of monitoring, evaluation and continuous improvement** in risk assessment processes (110). **5. Failure to mainstream climate risks** within broader health research, policy and practice (111).

BHAL 68: Strengthening NHS resilience through climate risk management

Photo by Simon Berger on Unsplash

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3.3 Integrated and responsive early warning systems

3.3.1 Overview

An early warning system collects, analyses, and communicates data on environmental and epidemiological signals with the goal of anticipating, and then informing a health response that limits climate-sensitive health impacts. It links meteorological, environmental, and health data to public health actions such as heat alerts, vector control or disaster preparedness.[BHAL 64] One estimate suggests an impressive degree of cost–effectiveness, with a 30% reduction in the economic damage caused by a disaster if an early warning is issued within 24 hours, resulting in an aggregate US$ 3–16 billion of annual loss avoided through widespread adoption of early warning systems (112). Similar examples of cost-effectiveness are found mirrored across the world.[BHAL 43] For example, WHO and WMO have estimated that scaling heat-health warning systems up globally could avert up to 100 000 deaths per year (113).

Between 2015 and 2023, the number of countries operating a national Multi-Hazard Early Warning System (MHEWS) doubled to 101, with approximately two thirds of the global population having access to effective early warning systems (114,115). This capacity is unequally distributed, with only 46% of Least Developed Countries (LDCs) and 39% of Small Island Developing States (SIDS) having access to an effective MHEWS (114).

The United Nations Early Warning for All (EW4All) initiative aims to ensure universal protection from hazardous hydrometeorological, climatological, and related environmental events through lifesaving multi-hazard early warning systems by the end of 2027 (114,116).

BHAL 64: Multi-faceted approach to heat-health in the Netherlands

BHAL 43: Protecting vulnerable people from extreme heat

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3.3.2 Designing single- and multi-hazard early warning systems

Early warning systems can be used for most climate hazards, ranging from heatwaves and wildfire to drought and vector-borne epidemics. They can be single-pathway- or multi-hazard-focused, with the former typically targeting one climate hazard that corresponds to a single primary exposure route.[BHAL 15] While these systems are easier to calibrate, operate and develop targeted mitigation strategies for, they obviously risk overlooking cumulative exposures from other hazards or secondary exposure routes. MHEWS monitor multiple hazards and multiple exposure pathways. They better represent real-world scenarios, though are typically more complex with significantly greater data requirements, technical challenges, and resource intensity.

When examined side by side, countries with limited to moderate MHEWS coverage have a disaster-related mortality ratio nearly six times higher than those with substantial to comprehensive coverage (4.05 deaths per 100 000 population, compared with 0.71) (117). In all cases, though, an early warning system is made up of four elements (93,118):

1. Risk knowledge, including scientifically supported thresholds for activation, escalation, and deactivation;
2. Detection, monitoring, analysis, and forecasting, accompanied by graded alerts;
3. Warning dissemination and communication; and
4. Preparedness and response capabilities.

Across multiple hazards, early warning systems have been found to be particularly cost-effective in reducing health impacts among at-risk groups, with the cost–effectiveness determined by a combination of technical accuracy, timely communication, action-orientated response plans, institutional support, and the degree of community engagement (95,119,120).

BHAL 15: Turning forecasts into lifesaving action

Defining locally appropriate dose-response relationships and thresholds, grounded in the epidemiological literature, is among the most important steps in EWS design. It enables the development of an impact–likelihood risk matrix, used to communicate to stakeholders who, in turn, determine response decisions aligned with risk levels (121). A rapid, often dynamic, public health risk assessment is typically undertaken in collaboration with meteorological service providers to determine if an alert will be issued and, if so, at what level of risk (122,123).

Data availability is key in developing an effective early warning system, with 10 years of recent weather and health data typically required to ensure effectiveness. In circumstances where epidemiological evidence is not available and cannot be modelled, hazard-based forecasting and warning can be developed instead.

The list below outlines key considerations in the design of an effective early warning system (124):

- **Lead time requirements**: Ensure that both the health sector and the public have sufficient advance notice to activate timely response measures, recognizing that different actions require different preparation times.
- **Forecast timing**: Issue forecasts early enough for stakeholders to implement necessary actions. Monthly and seasonal probabilistic forecasts can provide valuable insights to improve resource allocation and preparedness.
- **Confidence**: Clearly communicate the degree of confidence in the forecast and its predicted impacts to the end user.
- **Customized warning levels**: Tailor warning levels to local health risks and system capabilities, using colour scales (e.g., green to red) or numerical values (e.g., 0–4), and thresholds for calling and turning off these warning.
- **Modulation of actions**: Define specific risk levels that correspond to tailored measures for local and vulnerable populations.
- **Adaptability**: Align warning systems with local and regional frameworks, detailing measures to protect vulnerable groups.
- **Flexibility**: Maintain the ability to adjust and extend warnings to account for potential "out-of-season" events or concurrent risks that need to be reflected within the public health messaging (e.g., heatwave, wildfire, and air quality).

Finally, as demonstrated by the National Agency of Civil Aviation and Meteorology (ANACIM) in Senegal, codesign with communities and affected groups is perhaps the most important (and often overlooked) step in the design of an effective early warning system.[BHAL 35]

BHAL 35: Linking forecasts with lifesaving heat response

3.3.3 Operational ownership

Operational leadership of a health early warning system is typically a collaboration between meteorological services and a ministry of health or local public health authority, with a memorandum of understanding formalizing agreed triggers for escalation and deescalation (125).[BHAL 40] The early warning system is generally accompanied by an operational guide or framework, which sets out roles and responsibilities across the health sector, government, and voluntary sector at national, regional and local levels. Within the health ministry or public health authority, the operational leads for the warning system and associated framework are responsible for coordinating with emergency response colleagues and disseminating key information to senior officials and ministers. The public health authority will also typically lead on media and communications, with pre-agreed key messages and routes for dissemination, alongside responding to media enquiries via a designated spokesperson.

BHAL 40: Forecasting asthma risks to save lives

3.3.4 Communication and dissemination

Early warning systems channel critical information and alert decision-makers who, in turn, implement a range of predefined preventive actions and adaptation behaviours. Fig. 6 provides a real-world example of this process adapted from the UK Health Security Agency (UKHSA) weather-health alert system (125).[BHAL 1]

BHAL 1: Integrating forecasts into national health plan

Warnings should be disseminated through multiple channels, with information tailored to the intended audience (e.g., health agencies, hospital executives, clinicians or the general public) (126). Using a Common Alerting Protocol is essential for enabling automated dissemination, including SMS and smartphone-based warning messages (127). Warnings themselves should contain clear, concise, and actionable language and signpost to further official sources of information (128). As seen in the DARAJA early warning system in Tanzania, engaging communities in the development of warning tools (e.g., apps, social media) enables the tailoring of messages to their needs and perceptions, enhancing message comprehension, coverage and response. The project works with cities and informal settlements to protect populations from climate impacts, reaching over 800 000 residents in Nairobi and Dar es Salaam, enabling communities to take proactive measures in advance of adverse weather events (129). Similar examples of mass-volunteer mobilization can be found across the world.

Alongside broader public awareness campaigns, the system should be underpinned by formal end-user training for health professionals and the broader emergency responder community to support implementation and uptake, with a number of countries successfully implementing mass volunteer mobilization programmes.[BHAL 2] This training should outline how the EWS functions, the warning cascade and thresholds, and what actions should be taken at different warning levels (130).

BHAL 2: Mobilising communities in Bangladesh for cyclone resilience

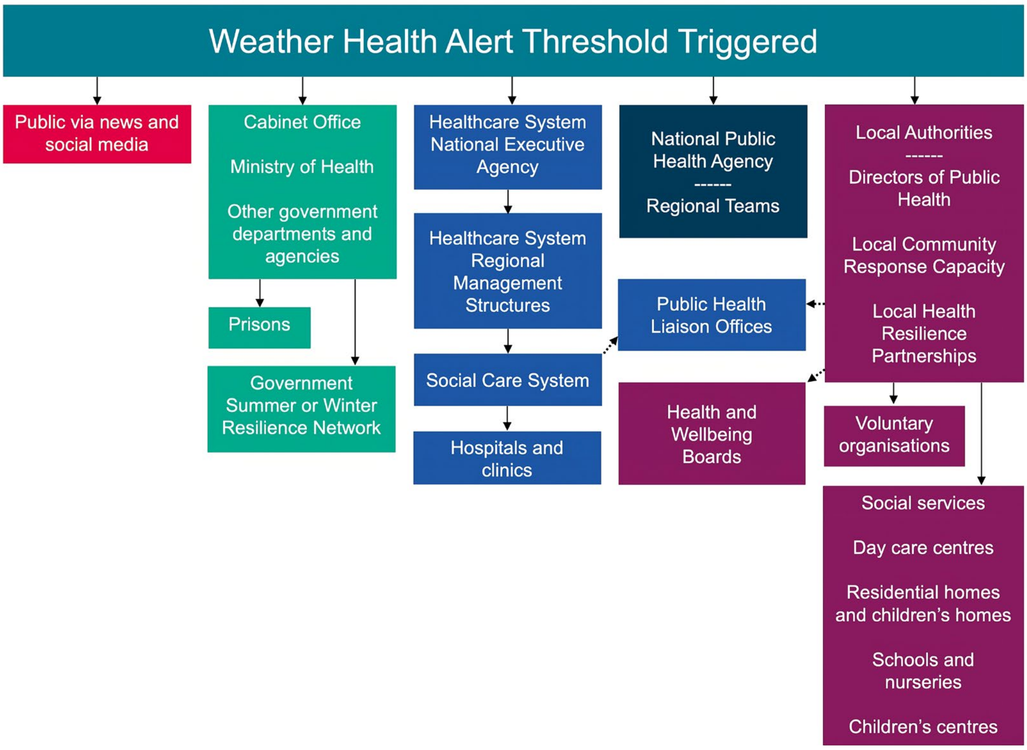


Fig. 6: Typical cascade of weather–health alerts (Adapted from UKHSA, 2024) (125).

3.3.5 Monitoring and evaluation of Early Warning Systems

Monitoring and evaluation are integral elements of an early warning system (131). This includes monitoring both process and outcome indicators, and the regular collection of data relevant to a functioning early warning system. Evaluations are best undertaken after the system has been operational for at least two years, to ensure the response system is established, and include consideration of its simplicity, acceptability, timeliness, sensitivity and specificity. Good evidence and frameworks exist for evaluating health warning systems, particularly for heat and flooding (Table 2) (132,133). A similar process and approach can be readily applied to other climate hazards and health pathways.

Longer-term, early warning systems need continuous iteration, evolving the response to a changing climate, demographics, and system capabilities (134). This evolution includes updating climate data to reflect increased severity and incorporating this within health impact models, recalibrating warning thresholds and revisiting geographic coverage.

Table 2: Criteria for evaluating a heat–health warning system (adapted from *Heatwaves and Health: Guidance on Warning-System Development* (WMO and WHO, 2015) (135)

Criterion	Description / Factors to Consider
Simplicity of the warning system and its operation	• Operational system (data required to issue a warning and institutions involved). • Management (time spent issuing warnings and maintaining the system).
Acceptability by stakeholders	• Collaboration between agencies. • Participation of institutions and stakeholders. • Completeness of response.
Timeliness of warnings	• Adequacy of timeliness of warnings for different response measures.
Sensitivity of warnings	• Ability of a warning forecast system to identify warning days (how often a forecast was correct in issuing a warning compared to observed meteorological or health data).
Specificity of warnings	• Ability of a warning forecast to identify non-warning days, thereby keeping false-positives to a minimum.

3.4 Climate change and health surveillance systems

3.4.1 Overview and types of surveillance

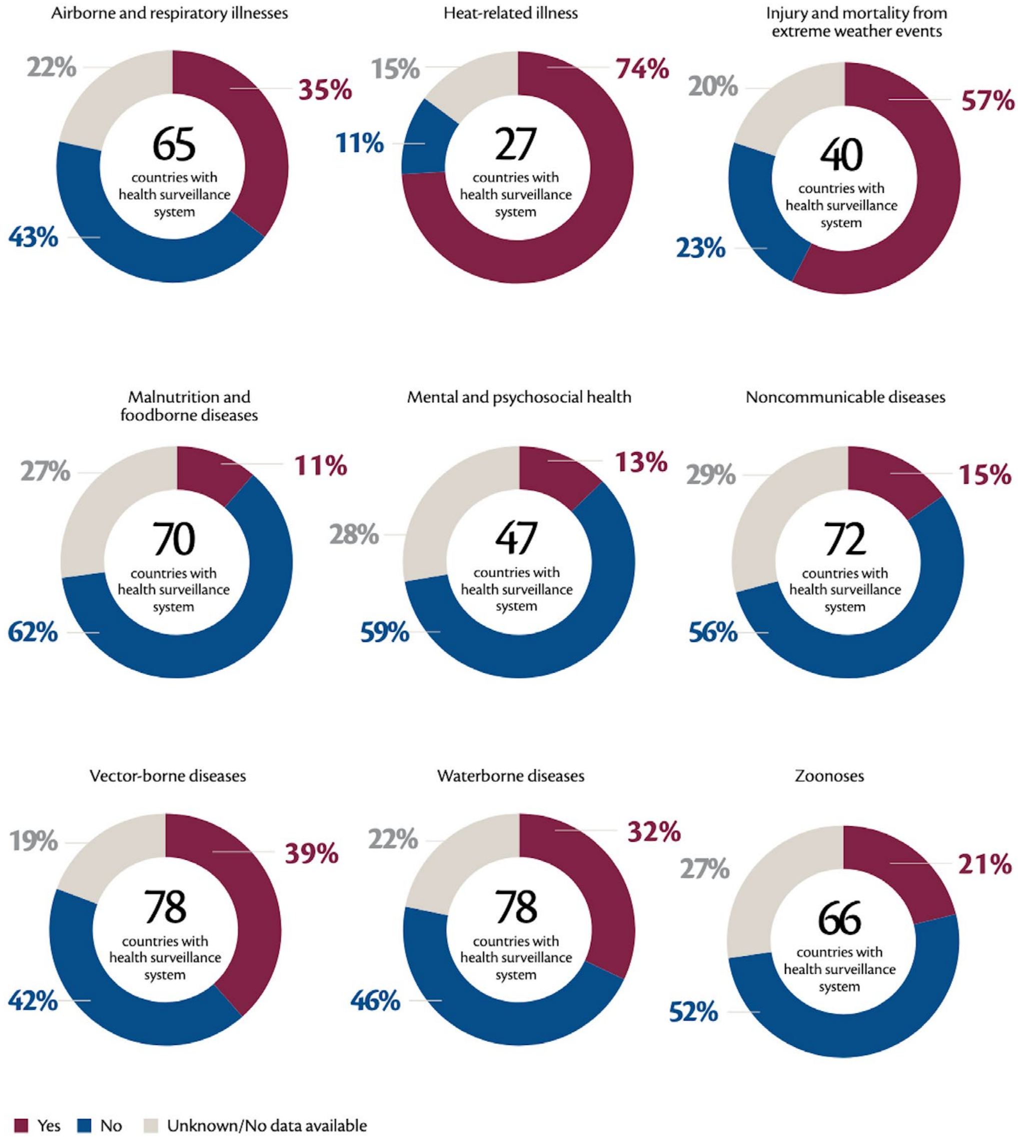
Weather and climate conditions have a significant impact on the incidence and geographical distribution of several diseases (136). Climate change and health surveillance refers to the systematic tracking and monitoring of health outcomes and indicators related to climate change. Surveillance is a critical component of managing the health impacts of climate change, identifying long-term trends and emerging threats, and informing strategic prevention and mitigation programmes (137,138).

While in practice there is significant overlap, at the broadest level, climate-sensitive surveillance systems can be categorized either by the data source considered or by the health outcome in question. For example, environmental and exposure surveillance monitors climatic and ecological conditions such as temperature, rainfall, vector ecology and air quality – each of which influence population health. Health impact surveillance tracks the occurrence and spatial distribution of climate-sensitive diseases and other health outcomes (139). Finally, health system surveillance observes service functionality, resource availability and adaptive capacity before, during and after climate stress.[BHAL 3]

BHAL 3: Linking weather data to healthcare in China

The WHO Health and Climate Change Survey provides a comprehensive overview of surveillance systems across the world and the extent to which they are integrated with national meteorological data. Surveillance systems focused on heat-related illnesses (74%) and injury and mortality from extreme weather events (57%) are relatively well connected to underlying meteorological data (Fig. 7) (140).

Fig. 7: Number of surveyed countries that reported having a health surveillance system in place (centre of chart) and the percentage of those health surveillance systems include meteorological information (140).



3.4.2 Surveillance design and data availability

Surveillance systems differ in their spatial and temporal resolution, and the health outcomes monitored. While some solely monitor mortality, more sophisticated systems include morbidity or suitable proxy indicators (141).

The most advanced surveillance systems combine mortality and morbidity data from multiple sources to build a comprehensive picture in real-time or for near-term forecasting.[BHAL 34] Typical infrastructure and capacity constraints can be overcome with innovative approaches, such as the use of community workers to conduct screening, testing, and data gathering in hard-to-reach areas, connected through community SMS networks (142). Bangladesh, Kenya, and Rwanda have all successfully piloted effective mobile-based mortality surveillance, while India has established verbal autopsy programmes to expand the reach of mortality data (143).

Beyond health outcome data, a wide range of health system data sources can be drawn on, including emergency room visits, family doctor consultations, medical helpline calls, hospital admissions and ambulance callouts. For example, an analysis of electronic medical records of over 4 million consultations with family doctors in the UK showed that heat-related consultations were particularly high among diabetics with cardiovascular comorbidities (144). Innovative "big data" sources can complement traditional surveillance, or be used when it is not available. These sources include media, social media, sickness leave, health insurance cost data and web searches that capture people's individuals and subjective thoughts before, during, and after an extreme weather event, and attempt to document health impacts (145,146).

It is important that surveillance data, often stratified by age groups, sex, or region, are interpreted with additional spatial information to identify the drivers of underlying vulnerability and relevant social inequalities. This approach recognizes that the health impact does not occur in isolation, but rather is determined by multiple factors including social, economic, environmental, housing, and geographical factors alongside exposure to the hazard itself. For example, the monitoring of overheating episodes within care settings can help contextualize risk and enable the identification of opportunities for intervention.[BHAL 56]

Of course, there are significant costs and technical challenges associated with building the national statistical capabilities needed to power these health information systems. Every added layer of data required, or disaggregation requested adds both fidelity and complexity to the model, leaving sophisticated systems difficult to develop for a large number of countries across the world without access to the financial resource, technology and capacity needed to implement them (147).

BHAL 34: Connecting data for faster disease control

BHAL 56: Mapping climate risks to guide action

3.4.3 Operational timescales for climate-sensitive surveillance systems

Health surveillance systems vary according to the nature of the risk, the type of data collected, and the decisions they are designed to inform. In practice, surveillance functions operate across three complementary horizons (133):

- **Continuous surveillance** involves the routine, uninterrupted collection of data on climate-sensitive health indicators and environmental exposures. It enables health authorities to detect emerging patterns of disease in real time (for example, gradual increases in respiratory illness during a period of transboundary haze) and supports the maintenance of up-to-date understanding of baseline conditions across regions and populations (133).

- **Event-based surveillance** is activated in response to an acute stressor, such as a flood, storm, or wildfire smoke episode. It captures short-term spikes in morbidity, mortality, and health service disruption, providing both the situational awareness needed to coordinate emergency response and the analysis to support post-event recovery (148).

- **Periodic surveillance** takes place at defined (often seasonal or multiyear) intervals, analysing accumulated data to identify long-term trends. This approach often underpins the decision support behind policy adjustments, or monitoring of a National Adaptation Plan (133).

Together, these operational timescales ensure surveillance systems are responsive to immediate threats, while also generating the evidence base needed for sustained, long-term resilience in the health sector.

Health surveillance systems should be routinely evaluated to improve effectiveness and ensure relevance (for example, are vector surveillance programmes accounting for changes in both geographic range and seasonality?), and the adoption of new and emerging technologies and data sources (131). Improvements to the surveillance system can in turn improve early warning systems. Incorporating new insights into operational protocols and alert thresholds can optimize forecasts and warnings, enabling timely protective measures.[BHAL 18]

BHAL 18: Empowering communities to monitor climate health in Brazil

3.5 Using health information systems to strengthen long-term resilience

Beyond the risk assessments, early warning programmes and surveillance already detailed above, health information systems form the analytical foundation for policy decisions that support long-term resilience. By consolidating all relevant data over longer time horizons, they can support decisions about where to invest in workforce capacity, health infrastructure and service redesign.

Delivering climate-informed health information systems is fundamentally dependent on the quality, granularity and accessibility of climate and meteorological data. Health systems cannot anticipate or adapt to changing risks without strong, well-resourced national meteorological and hydrological services that can generate, interpret, and share high resolution climate data in formats usable by the health sector. This requires investment not only in forecasting capacity and data infrastructure but also in institutional collaboration – ensuring that both meteorological agencies and health ministries are equipped, mandated, and incentivized to engage meaningfully with their counterparts (Box 3).

One such example of this is seen in the Joint Climate and Health Programme between WHO and the World Meteorological Organization (WMO), which works to build guidance, data standards, capacity and operational partnerships that bridge climate science and public health practice. Its work demonstrates how integrated platforms can translate meteorological information into health-relevant insights, such as seasonal disease forecasts or climate-informed vulnerability assessments (149).

Box 3

Climate services for health as a pivotal adaptation tool

In sectors as diverse as agriculture, water, transport, and disaster risk management, climate services help countries, companies, and communities prepare for climate-related risks at the scale of days to decades. In the health sector, climate services can be used to:

- **Monitor and forecast health-relevant hazards** such as heatwaves, floods, droughts, wildfires, and vector-breeding conditions.
- Inform **surveillance and early warning systems** for climate-sensitive diseases (e.g., malaria, dengue, cholera) and for events such as heat stress or air pollution spikes.
- **Support preparedness and response by helping decision makers** activate public health campaigns, pre-position medical supplies, or adjust hospital staffing.
- **Strengthen planning and policy** by integrating climate projections into vulnerability assessments, adaptation strategies, and national health plans.
- **Promote innovation and resilience** through climate-informed facility design, logistics, and digital health systems that ensure continuity of care during extreme events.

Notably, climate services support all three action lines of the Belém Health Action Plan. This includes:

Action Line 1: Climate services can help **strengthen surveillance and monitoring systems** by integrating environmental and meteorological data with public health information to better detect, anticipate, and respond to climate-sensitive risks. Forecasts of temperature, rainfall, and extreme events can trigger early warning systems for heat stress, vector-borne diseases, and water-borne outbreaks.

Action Line 2: Climate services **provide the evidence base for climate-informed health planning** and investment. Historical and projected climate data help identify the regions and populations most at risk, supporting vulnerability assessments and priority-setting within national adaptation plans for health. They also enable evaluation of the health co-benefits of actions in other sectors.

Action Line 3: Climate services can support the use of data on temperature, precipitation, and flood risk to anticipate surges in demand for medicines, vaccines, or vector-control supplies. Long-term climate projections can also inform **investments in new technologies** and resilient infrastructure to ensure uninterrupted operation of health care services during extreme climate events.

Across the literature, there is good evidence supporting the application of climate-informed information systems to three different components of health system resilience:

- The design and targeting of programmes and clinical services using climate-linked data to identify which populations and conditions are most sensitive to climate risks, guiding the location and focus of prevention, preparedness, and clinical intervention efforts.

- Decisions related to health infrastructure locations and physical adaptation requirements, mapping facility data against exposure and hazard layers to support decisions on where to build, retrofit, or reinforce hospitals and clinics, ensuring that essential services remain operational during floods, heatwaves, and other climate-related events.

- Health workforce planning, linking capability and capacity assessments with climate projections, to anticipate changing health needs and workforce demands.

Each of these are summarized below, and the evidence and literature are addressed directly in the subsequent sections.

3.6 Conclusion

Health information systems are a core component of climate-resilient health systems, providing the data and analytical foundation for informed decision-making. They enable the integration of environmental, health and system data to guide emergency response, adaptation planning, workforce development and infrastructure investment. While progress is accelerating, global coverage remains uneven and the evidence base on second order and downstream effects, and on effective implementation in low-resource settings, is still limited. Importantly, these information systems are often only as good as their integration with decision-making and the corresponding response-capacity. A strong degree of international and regional coordination is required, with emerging examples ranging from WHO-WMO Joint Programme and the Lancet Countdown to the Institut Pasteur’s work across southeast Asia.[BHAL 58] Strengthening these systems through improved interoperability, sustained financing and technical capacity is essential if decision-making is to remain evidence-based, equitable, and responsive to evolving climate risks.

BHAL 58: Integrating climate intelligence into disease control

Action Line 3

Building capacity for climate-resilient health systems

Photo by Kathryn Johnson

Introduction

Successfully building a climate-resilient health sector is dependent on the strength of its underlying capacities: infrastructure, workforce, governance and finance. These elements determine whether clinics and countries are able to anticipate, prepare for, and respond effectively to climate change.

Action Line 2 of the Belém Health Action Plan is focused on evidence-based policy, strategy, and capacity-building. This section addresses this along four critical axes. It begins by examining the evidence and adaptation interventions available to protect physical healthcare infrastructure, medical supply chains, and the energy, information, water and transport systems they depend on. Moving from the fixed assets to the nurses, doctors and public health professionals that bring them to life, the second subsection considers adaptation interventions in the health workforce. The third and fourth subsections focus on governance and leadership, and the financial resourcing needed for implementation.

Delivering on the commitments underpinning the Belém Health Action Plan requires a comprehensive approach that strengthens these four components. Doing so will enable countries to operationalize climate and health strategies, protect vulnerable populations and ensure that health systems remain reliable, efficient and equitable in a changing climate.

4.1 Healthcare infrastructure and supply chains

Recommendations

1. **Prioritize the expansion of primary care capacity as anchor institutions for local communities**

   A dense network of primary care centres with on-site or backup utilities reduces the need for patients to travel for care and is perhaps one of the most effective interventions available. These clinics serve as anchor institutions and first points of contact during extreme events, providing continuity of essential services and community-based responses when hospitals are overwhelmed.

2. **Design for backup of distributed utilities to ensure continuity of critical services**

   Maintaining continuity of care at hospitals and other urgent care centres is essential at all times, especially when healthcare demand spikes during a disaster. Critical health facilities require backup systems for electricity, increasingly from on-site renewables and battery storage. The use of microgrids and other distributed energy systems such as district heating and cooling systems allows for continued operations even when electricity and fuel infrastructure is disrupted.

3. **Leverage efficiency programs to reduce the impact of extreme events**

   Investing in efficiency programs directly lowers healthcare's resource demand, often with substantial financial savings over time. In turn, this allows backup systems to be smaller, saving on capital costs and reducing the space requirements for such equipment. Deep energy retrofits through upgrading lighting, building envelopes, and heating, ventilation, and air-conditioning systems may allow a health facility to meet all its electricity needs through on-site renewables with battery backup.

4. **Secure essential health supply chains against climate disruption**

   The continuity of essential medicines, equipment, and logistics underpins every aspect of health system resilience. Mapping supply vulnerabilities, diversifying production and storage geographically, and investing in regionally networked distribution systems are important foundations alongside innovations in cold chains and heat-stable pharmaceuticals.

Safeguarding the physical infrastructure that underlies all public health and clinical services is a key strategy in developing a climate-resilient health sector. At the facility level, climate resilience is defined as the ability "to anticipate, respond to, cope with, recover from and adapt to climate-related shocks and stress, so as to bring sustained improvements in population health, despite an unstable climate" (150). However, healthcare's physical infrastructure includes not only the facilities where care takes place, but also the energy, water and communication utilities that support them, the roads and transportation networks that enable access, and all of the entities that supply medicines, equipment and other goods and services. Many supply chains are global and lack sufficient redundancy, such that climate disruptions to a single key facility may reverberate through multiple countries, interrupting essential care for millions.

Unlike in other sectors, disruption to health services or health supply chains brings almost immediate – often life-or-death – consequences to patients and populations (151). Healthcare facilities provide lifesaving care daily, necessitating greater resilience and redundancy than almost any other sector, with significantly higher consequences if systems fail. This vulnerability is compounded by the sector's role as a responder. Healthcare infrastructure is simultaneously susceptible to climate disasters and central to responding to them. Healthcare also faces unique operational complexities. Inpatient facilities care for people in their most vulnerable states – injured, recovering, undergoing complex treatment, and potentially with limited or no mobility – creating greater challenges in disaster management and evacuations compared to other sectors.

4.1.1 A global overview

With over 200 000 hospitals and millions of clinics and health facilities globally, providing any kind of reliable quantitative assessment of climate readiness of health infrastructure is inherently difficult. Nonetheless, one recent study suggests that under high warming scenarios, the number of hospitals at risk of total or partial shutdown due to extreme weather is set to double, to over 16 000 globally (5). Parts of Asia are among the worst affected, with the risk of shutdown increasing to over 5,800 and 3,200 hospitals in South Asia and East Asia, respectively, by the end of the century, under Representative Concentration Pathway 8.5 (RCP8.5). In the case of Southeast Asia specifically, this represents almost one in five hospitals at high risk of total or partial shutdown by the end of the century (5).

Photo by Patrick Hans Mulindwa

One review of health adaptation planning across 82 countries demonstrated that only 6% currently have systems in place to monitor the effects of climate change on healthcare infrastructure (152). This reinforces findings from a WHO assessment of 86 NAPs and HNAPs concluding that only 54% of plans specifically assessed the risk climate change posed to health facilities, and only 51% proposed at least one action to address this risk (101).

National health systems are at different stages of development in building adaptive capacity and expanding universal health coverage, and within countries there is often a wide range of readiness across regions or localities (153,154). While a set of consensus metrics that quantitively summarize the physical resilience of health systems does not yet exist (though there are many candidates), a review of the literature reveals three general stages of healthcare infrastructure resilience. These can be read alongside Fig. 8, providing a conceptual path of evolution that can be useful in tracking progress on physical resilience over time (154,155).

- **Underdeveloped**: These systems are not meeting current needs, based on existing national climatic conditions. Physical infrastructure is failing to provide safe conditions for patient care under routine weather events, due to undercapacity, lack of maintenance or improper design, leading to measurable public health damages. Extreme events cause mass closures of facilities, collapse of healthcare supply chains and significant delays in restoring services.

- **Baseline**: These systems maintain safe operations under current climatic conditions, with any failures quickly addressed. However, extreme events still cause extensive damage as facilities are designed to standards based on historical climate conditions.

- **Climate-resilient**: These facilities operate smoothly, with multiple redundant systems, and have designed their physical infrastructure to standards that incorporate expected intensification of climate change. Extreme events still cause limited damage but do not substantially impair healthcare services, as facilities are quickly brought back online or patients can be easily transferred to contingent facilities.

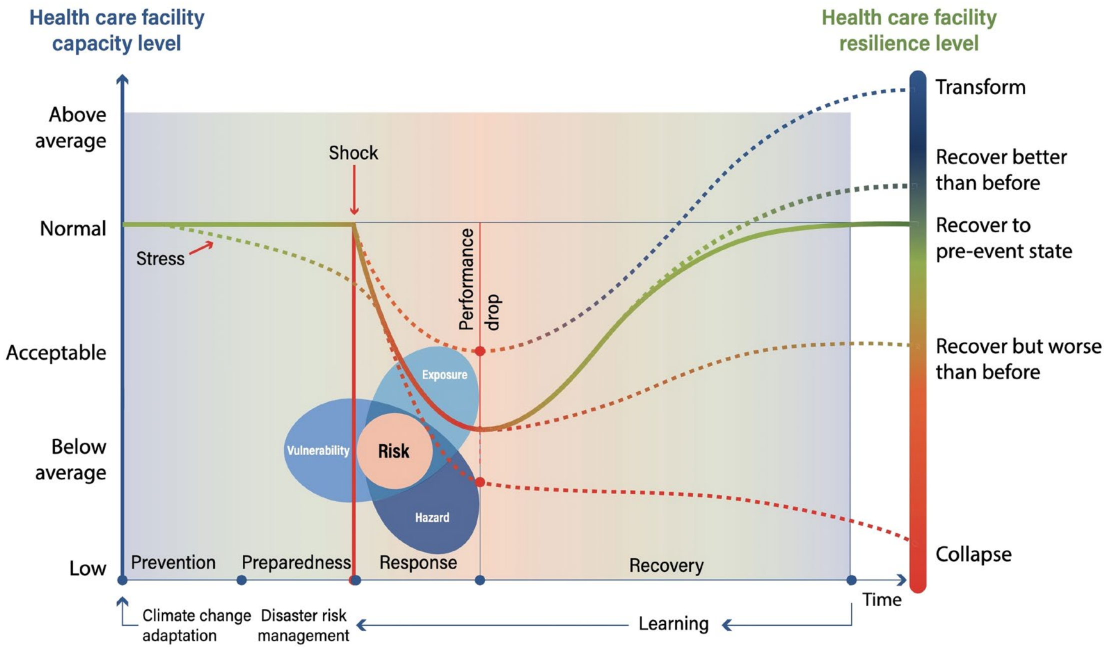


Fig. 8: Health system capacity and resilience over time (156).

4.1.2 Healthcare infrastructure: the state of the literature

Concerns over the reliability and safety of healthcare's physical buildings and infrastructure have existed ever since the advent of centralized medical services, though they began to receive attention in the literature around the mid-1940s, with a focus mostly on energy reliability. The next several decades saw an accumulation of case studies demonstrating how hospital structures and connected utilities can be disrupted by various types of environmental disasters, and how to avoid these disruptions through architectural and engineering design. With the advent of infrastructure resilience research in the 1990s, healthcare's physical facilities became a primary focus of climate adaptation policy as a critical lifeline system (157).

Research on climate adaptation and resilience in health systems published in the scientific literature falls primarily into three categories.

First are studies that document the physical and economic risks and damages to health facilities. These are typically framed around physical hazards and the vulnerability of healthcare's physical assets. Numerous regional studies have identified healthcare facilities in low-lying islands, in floodplains, or in coastal regions as particularly vulnerable (158,159). In Pacific Island countries, for example, approximately 62% of healthcare facilities are located within 500 metres of the coast (160,161). The literature also makes clear that damages to the infrastructure systems that support healthcare facilities can be just as crippling to healthcare services as damages to clinics and hospitals, and offers frameworks for assessing vulnerabilities and the risks of "cascading failures" (5,162).

When extreme events do occur, they tend to cause more damage to healthcare facilities in LMICs, often operating with reduced adaptive capacity. For example, the 2022 flooding in Pakistan damaged or destroyed 13% of all healthcare facilities, affecting care for tens of millions of people (161). Populations in LMICs tend to have a higher level of climate vulnerability as well, experiencing roughly three times as many fatalities from disaster events compared to HICs, which puts additional stress on local healthcare systems (163).

A second category of research consists of case studies from individual health systems or facilities that have taken various adaptation actions. This is a broad area of research, both in terms of geography and discipline, but reviews have compiled the most common types of adaptations strategies. For example, roof modifications (for heat and precipitation), utility relocation (for flooding) and water supply management (for flooding and drought) were the most commonly analysed adaptation strategies within this category of study (164).

The third general category presents evidence-based guidance on resilience strategies that can be applied to healthcare's physical facilities and infrastructure. It typically includes global- or national-level generalized concepts, frameworks, indicators, scoring systems, technical requirements, and simple lists of best practices (165).

4.1.3 From evidence into action

Moving from the literature and into real-world intervention requires a change in focus to three dimensions of health adaptation. First, *baseline access* describes the relationship between existing infrastructure and growing demand for healthcare services. Second, *healthcare facility capacity* describes the level of readiness and adaptation of clinics, hospitals, and other care sites and their ability to provide necessary services in the face of climate change.[BHAL 54] Third, *cross-sectoral systems capacity* describes the resilience of lifeline systems and supply chains that are external to clinical services, but without which healthcare operations cannot be maintained.

BHAL 54: Strengthening hospitals for a changing climate

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4.1.4 Dimensions of baseline access: expanding care to meet new demands

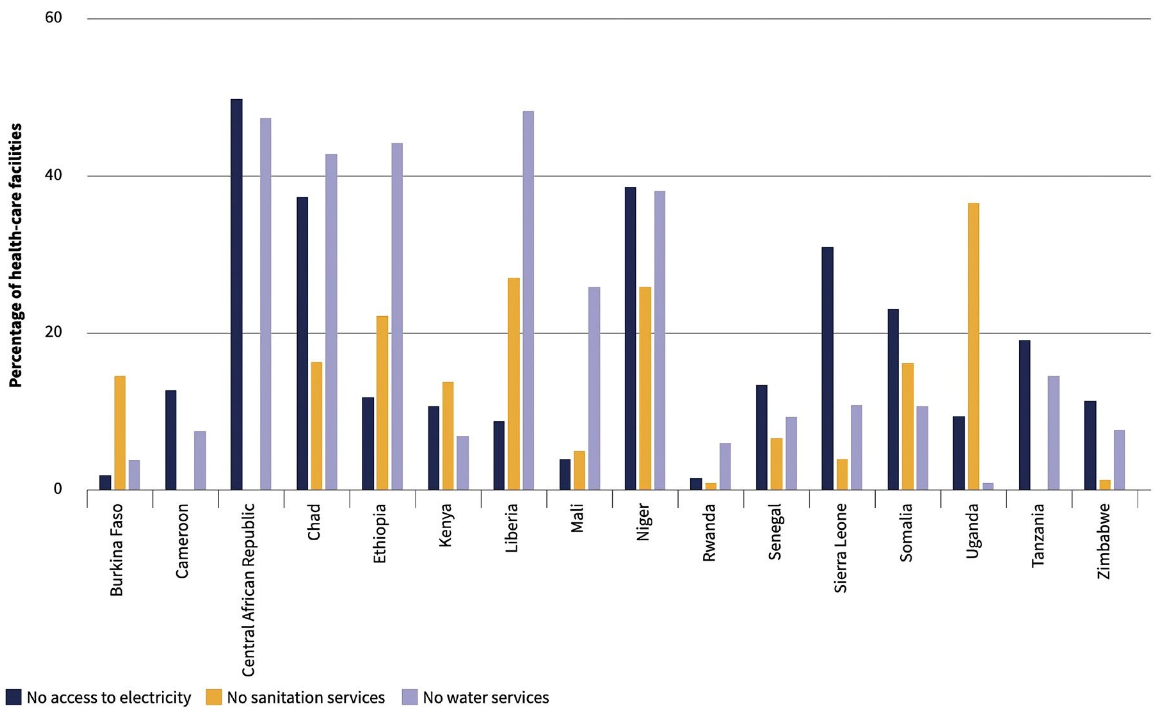
The WHO Service Availability and Readiness Assessment (SARA) makes the infrastructure dimensions of baseline access to public health and clinical services clear (166). This includes basic physical infrastructure and utilities, such as facilities that protect patients and staff from the elements and maintain a safe temperature, climate-controlled if necessary. Facilities must have sufficient water, sanitation and hygiene (WASH) infrastructure, including reliable access to clean water, safe waste disposal and storage (for non-hazardous and hazardous medical waste), and a reliable source of power.[BHAL 11] They also require basic services, such as communication equipment and internet-connected computers, emergency transport, safe storage for medicines and vaccines, and diagnostic capacity. After basic infrastructure and amenities, health systems require the necessary medical devices and equipment to deliver highly specialized care, ranging from pathology and diagnostic services to surgical suites and intensive care units.

BHAL 11: Building climate-smart waste systems across South Asia

Climate change intensifies the urgency of building and sustaining this baseline access, particularly for primary healthcare. In Benin, where the incidence of malaria is projected to increase due to higher humidity and warmer temperatures, new primary care facilities, enhanced supply chains and surveillance networks are required (167). In many countries, additional primary care services are needed to deliver baseline care, and it is essential to integrate climate resilience while developing this capacity.

To this end, strengthening resilience must account for countries where such infrastructure is currently insufficient. Extreme weather events, shifting risk landscapes, and increasing resource strain disproportionately impact the most vulnerable populations with inherently lower existing adaptive capacity (168). To place this in context, in 2022, approximately 1 billion people in low- and middle-income countries were served by healthcare facilities either lacking access to electricity or with an unreliable electricity supply (Fig. 9).[BHAL 55] In 2023, 1.1 billion people were served by healthcare facilities lacking basic water services. In the 60 most vulnerable countries, home to some 2 billion people, more than a third of facilities lacked basic water services and only 19% had access to basic sanitation services (169).

BHAL 55: Building climate-ready health infrastructure in Nigeria



Note: National data on sanitation and water services in health-care facilities produced by the WHO/UNICEF Joint Monitoring Programme for WASH were used.

Fig. 9: Percentage of healthcare facilities lacking electricity (2015–2022), sanitation, and water services (2018–2021) in selected sub-Saharan African countries (170).

While climate change presents significant challenges to achieving universal health coverage, it also presents an opportunity to develop equitable strategies that address both goals concurrently (171). While established health systems are often constrained by previous infrastructure decisions (made based on assumptions of healthier demographic profiles or more hospitable climates), countries with expanding health services in rapidly emerging economies are able to integrate climate considerations into health infrastructure planning from the outset, offering a chance to build infrastructure that is more resilient, safeguards long-term investments and expands access to care.

4.1.5 Dimensions of healthcare facility capacity: building for a changing climate

Siting & Construction

As discussed in Section 3, climate-informed health information systems can provide critical support in deciding where new facilities are sited and how they are constructed. Capital project planning and siting decisions must account for both current and projected risks, avoiding the constructing of new healthcare facilities in areas highly vulnerable to climate hazards, such as flood zones or areas subject to rising sea levels (172). In cases where healthcare facilities must be built in higher-risk areas, construction decisions can be made to mitigate that risk.[BHAL 8]

Health infrastructure can also implement low- or no-cost design solutions that put less strain on facility services during climate shocks. Many of the interventions available have been known and deployed by local communities across the world for decades if not centuries. This has been demonstrated by a regional hospital in Equatorial Guinea, where site planning prioritized green areas for rainwater infiltration and the layout enabled natural ventilation and daylighting, contributing to greater climate resilience and continuous operation during disruptions (173). Only once these straightforward and cost-effective interventions have been deployed should high-tech interventions be considered, and even then, only considered when the specific context calls for it. Ng Teng Fong General Hospital and Jurong Community Hospital exemplify passive cooling through their use of natural ventilation, strategic facility orientation, and green infrastructure. The design includes wards shaped to facilitate air flow, with operable windows and vertical vegetation. These interventions not only maintain comfortable indoor conditions in Singapore's tropical climate but significantly lower energy demand, improving system resilience in low power events (174,175).

BHAL 8: Building safer, climate-ready hospitals

The adoption of climate-resilience building codes is one of the single most important interventions available to countries and health services. Evidence has long shown that building codes effectively establish a minimum level of protection against external environmental risks, and the benefits of implementation have been demonstrated globally (164). One comprehensive cost–benefit study found that adopting and implementing model building codes yields a benefit of US$ 11 in avoided losses for every US$ 1 invested (176,177). Despite these returns, it is estimated that only 15% of healthcare organizations globally are deploying climate-resilient building codes for new construction (178). Critically, these building codes, especially those for critical healthcare facilities and infrastructure, should be updated to incorporate projected climate risks, and refreshed on a regular basis to ensure they adhere to the best available science and knowledge.

High-stress contexts

To provide continuous, high-quality care under periods of climate stress, healthcare facilities must proactively develop capacity to operate during times of high demand such as floods, heatwaves, and climate-related disease outbreaks. These scenarios require infrastructure capable of dealing with increased patient loads and strains on essential services, such as energy and water supplies. During Hurricane Katrina in 2005 in the USA, Veterans Administration Hospital in New Orleans was damaged beyond repair. The hospital that replaced it put the emergency department on the second floor, moved all utilities to the top of the building, and built enough backup capacity, food and storage to allow for five days of completely isolated operation (179).

Drawing on lessons from the world of pandemic response, developing surge and temporary expansion capacity enables health systems to absorb increases in patient demand while maintaining the ability to deliver essential routine care (153,180). At

Photo by Mark König

the community level, cooling centres and novel discharge solutions can reduce health system stress during extreme heat events (181).[BHAL 33] Importantly, though, the capacity to temporarily increase services is often expensive and difficult to sustain for even the most well-resourced health service. In this event, proper clinical triage planning is important to reduce pressure on health systems from nonurgent or nonessential care demands.

BHAL 33: Acting early to beat the heat

Materials

Throughout the sustainability literature, the ability to maximize the use of scarce resources through reuse and reprocessing is often highlighted as an important resilience measure during disaster response, times of high system stress or supply chain disruption. As demonstrated by the COVID-19 pandemic, reprocessing and reuse capacity onsite boosts the resilience of facilities, helping them withstand severe disruptions without interrupting routine care (182).

Similarly, the reprocessing of medical devices, surgical instruments, and personal protective equipment can reduce vulnerability to supply disruptions during extremes of weather or transport interruptions. Resterilizing equipment or recycling water in dialysis units through safe and quality-assured processes lowers resource demand and helps facilities continue operating during heatwaves, droughts or power shortages (183,184).

4.1.6 Dimensions of cross-sectoral systems capacity

Safeguarding critical services

Climate shocks threaten the essential services that healthcare facilities rely on – energy, water, sanitation, waste management and communications – by damaging and straining critical infrastructure. Energy demand can spike during a heatwave, and water shortages can compromise water supply and sanitation. To strengthen energy resilience, the literature suggests elevating generators and batteries, installing redundant backup power systems, and investing in decentralized energy sources such as microgrids (158). Technologies such as onsite combined heat and power systems and onsite reprocessing and resterilization services can provide additional resilience benefits, improving efficiency, cutting costs, and reducing emissions.[BHAL 20] For water supply and sanitation, backup storage tanks, underground wells, additional pipelines, and separating process water systems from potable water systems are all proven to be effective (185).

One example of cross-sectoral system redundancy is seen in Partners in Health's University Hospital (HUM) in Mirebalais, Haiti, the largest solar-powered hospital in the Caribbean. The local electricity grid is unreliable and expensive, and operating as an independent microgrid has allowed HUM to save costs and ensure consistent energy supply necessary to provide care (186).

BHAL 20: Treating waste, protecting Maldivians' health

Telemedicine

As discussed in Section 3, building capacity for digitally enabled care can support continuous access to healthcare during climate-related disasters that otherwise disrupt physical infrastructure(187).[BHAL 49] In one instance during Hurricane Florence in 2018, telemedicine proved effective in enabling clinicians to provide preliminary assessments of evacuees remotely, deferring transport for 35% of potential patients who would otherwise have gone to the hospital, further straining an already overburdened facility (188). However, this same technology also brings risk. During a 2022 European heatwave, two of London's largest hospitals lost access to electronic medical records after IT systems overheated and failed, significantly impacting operations and delaying care for thousands of patients across multiple days (188).

BHAL 49: Leading Egypt's health-climate transformation

Resilient supply chains

Healthcare supply chains face multiple climate-related risks, ranging from disruptions to manufacturing and transport from extreme weather events to unplanned spikes in demand for services and pharmaceuticals. A recent Asian Development Bank review demonstrates the impact this can have on care, and recommends a series of interventions to mitigate that risk (88). As with health facilities, manufacturers must assess climate risks and engage in climate-informed infrastructure planning, retrofit older facilities to withstand future climate risks, and avoid siting new facilities in areas of high risk.

Even if manufacturing facilities are unaffected by climate risks, healthcare supply chains are vulnerable to transportation and distribution disruptions. During severe flooding in Bangladesh, nearly 50% of pathology lab shipments were delayed, impacting testing for infectious diseases (189). This highlights the need to strengthen public transportation networks, avoid overreliance on a single supplier or geographically concentrated suppliers, and prioritize shorter supply chains.

Rising temperatures place supply chains under direct threat too, with one study suggesting that the lifespan of pharmaceuticals and medical equipment can be reduced by as much as 25% in high-humidity environments. In response, Brazil's national laboratories have implemented humidity-controlled environments using energy-efficient air conditioning and dehumidifiers (189). Interventions can also take place at the design stage, increasing durability and shelf life of medical equipment, products, and packaging. Critical pharmaceutical cold chains are clearly vulnerable to climate disruption. In one study across sub-Saharan Africa, up to 40% of vaccine wastage across the region was linked to cold chain failures caused by power instability (161). Accounting for rising temperatures and the resilience of refrigerated storage areas, solar-powered (or solar-direct drive, SDD) refrigeration has revolutionized vaccine storage for rural African clinics.[BHAL 37] During Cyclone Ana and Cyclone Freddy in Malawi in 2021 and 2023, vaccines stored in solar-powered fridges remained undamaged, allowing continued routine vaccination. Malawi has implemented this intervention across nearly all vaccine storage facilities, building climate resilience and expanding immunization access to communities who need it most (190). Gavi, the Vaccine Alliance, has funded more than 41 000 SDD refrigeration units around the world (161).

BHAL 37: Solar innovation for maternal and child health resilience

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Addressing the same issue through a different innovation, UNITAID's work improving heat stability in essential antimalarials and antiretrovirals demonstrates how technology can enhance both access and resilience. By developing formulations that remain effective without refrigeration, the work helps maintain treatment continuity during extreme heat events and power outages, particularly in regions where cold chain infrastructure is limited.[BHAL 6]

BHAL 6: Safeguarding health products in a warming world

Stockpiling essential medicines and medical products

While formal health systems can only influence supply chains indirectly, they can directly prepare for disruption by maintaining and monitoring strategic reserves of essential supplies, such as vaccines, medicines, IV bags and other disaster response supplies. For example, this year, Pakistan's health system began prepositioning more than 300 000 essential medical items in facilities across the country as part of the national Monsoon Contingency Plan 2025 (191,192). Establishing regional and strategically located stockpiling centres, as seen in UNFPA's Regional Prepositioning Initiative, is similarly effective. For over a decade, reproductive health supplies have been stored at regional hubs, making essential supplies immediately available to vulnerable populations during disasters (193).

4.1.7 Conclusion

Ultimately, climate-resilient healthcare infrastructure is not solely an engineering challenge, but also a systems one. Facilities, supply chains, and critical utilities must be planned, built, and managed as integral components of health system capacity, and supported by skilled staff, coherent governance and sustainable financing.

As the academic literature reveals, and the Belém Health Action Plan underscores, resilient infrastructure enables continuity of care, safeguards universal health coverage, and anchors community trust in times of crisis. Delivering this transformation requires aligning technical standards, financing mechanisms, and political commitment to ensure that every health facility is designed to be ready for a changing climate while continuing to serve the people who depend on it.

4.2 A climate-ready health workforce

Recommendations

1. **Embed climate-smart workforce development in all climate and health policy**

   Do this by prioritizing three complementary strategies: 1) targeted continuing education for practicing professionals; 2) integration of climate competencies into preservice curricula; and 3) structured multidisciplinary engagement to build professional connections between sectors, and across mitigation and adaptation.

2. **Mandate climate and health competencies in accreditation and regulation**

   Require core competencies for all health professionals, utilizing accreditation standards and established regulatory frameworks as entry points, supported by adequate resources invested into teaching and faculty development.

3. **Direct financing and workforce capacity to LMICs and underserved professions**

   Prioritize training and workforce development efforts in LMICs, and for community health workers, allied health professionals, health administrators and policy-makers in all countries.

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4.2.1 A thriving health workforce to drive climate resilience

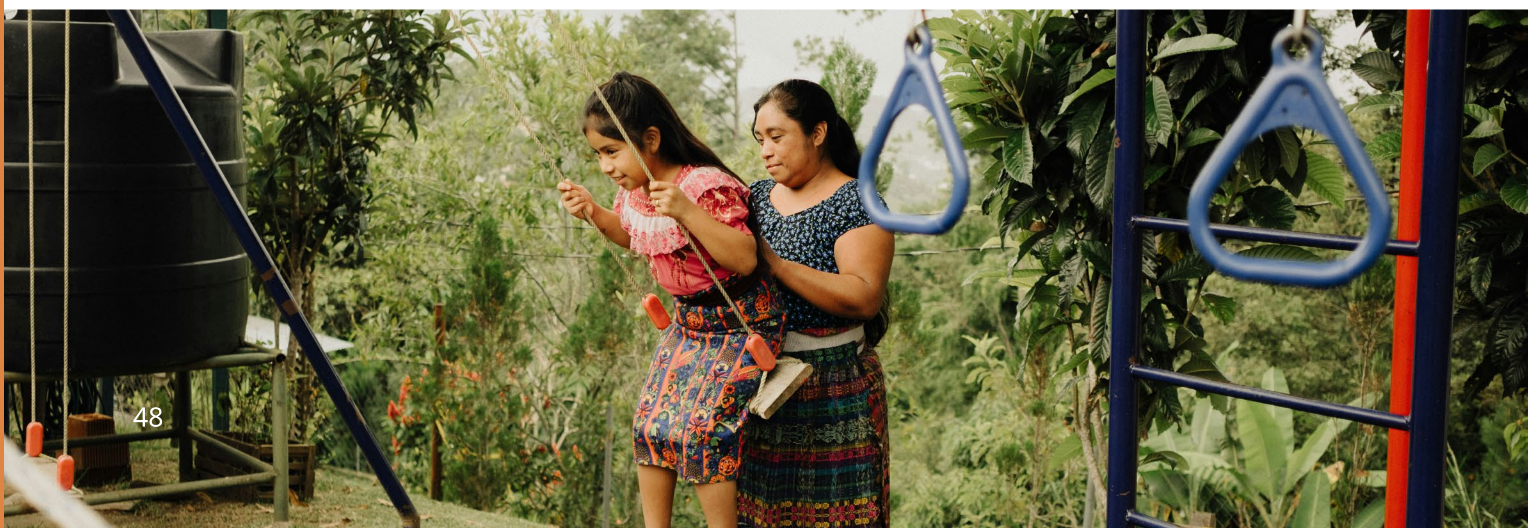
Nurses, doctors, pharmacists, and the broader health professions are the lifeblood of a health system. Alongside physical infrastructure, workforce capacity and capability are the foundation upon which all climate change adaptation and mitigation interventions depend. This transcends individual professional competence to encompass the collective ability of health systems and health-determining sectors to anticipate, respond to, and recover from climate-related health challenges.[BHAL 67] Without adequately prepared professionals embedded within resilient institutional frameworks, even the most well-designed policies and programmes will fail to protect communities from escalating risks (72,194). Simultaneously, professionals operating within health-determining sectors must develop awareness of how their decisions create ripple effects throughout the determinants of health.

Across all countries, approximately 65.1 million health professionals serve 8.2 billion people. At 29.1 million, nurses make up nearly half of the health workforce, followed by doctors (12.7 million), pharmacists (3.7 million), dentists (2.5 million), midwives (2.2 million) and 14.9 million members of the wider public health community (67). The WHO Global Strategy on Human Resources for Health projects a 29% increase in health workforce from 2020 to 2030, growing at three times the forecasted population growth rate (9.7%) over that period (195). Critically, the global distribution of the health workforce is unequal, with the density of health workers 6.5 times higher in high-income countries compared to low-income countries. Worse, in an absolute sense, best estimates predict a shortage of 10–18 million people in the global health workforce by 2030 (67). Applying this to climate change, the 2021 WHO Country Survey indicates that 54% of responding countries view limited human resource capacity as a critical barrier to implementing national climate and health plans (140).

The focus of this subsection is on health workforce capabilities, rather than capacity. It is structured around a comprehensive review of the literature, assessing the state of health workforce preparedness as well as strategies to enhance capabilities in all health and health-determining professions, before concluding with recommendations for health systems and national health ministries.

BHAL 67: Building a climate-ready health workforce in Nepal

Photo by Shelby Murphy Figueroa on Unsplash



4.2.2 Climate change and the health workforce: the state of the literature

A systematic literature review of the intersection of climate change and the health workforce was conducted, focusing on research published in the last decade. A comprehensive PubMed search identified studies addressing training, education and professional development for all forms of health professional focused on climate change and health. Search terms combined health professional categories, capacity-building interventions, and climate-related exposures such as extreme weather, temperature extremes and air pollution.

The search strategy revealed 713 studies, which underwent title and abstract screening by two independent reviewers. Conflicts were resolved through group discussion among four reviewers, yielding 147 studies. A further 28 were excluded based on predefined inclusion criteria (see Appendix 1), with 119 papers included in the subsequent analysis.

Each of the panels in Fig. 10 provides an overview of the literature, with several notable trends. First, the absolute numbers of papers included is comparatively low. This is in part due to strict inclusion criteria that focused on novel, high-quality studies, and in part due to the nascent nature of the field. Despite this, there is clear growth in the literature, signalling expanding interest in capacity building. Geographical analysis demonstrates pronounced regional disparity, with studies concentrated in the United States (45), Australia (9), and Canada (7). Though 22 studies were global in nature, representation of studies focused on workforce capacity in LMICs was limited. Perhaps reassuringly, descriptive and intervention studies rather than editorials dominated the review, though meta-analyses and reviews were notably infrequent, indicating a paucity of large-scale evaluations identifying best practices or comparative effectiveness.

This systematic review underpins the intervention and policy-focused subsections below.

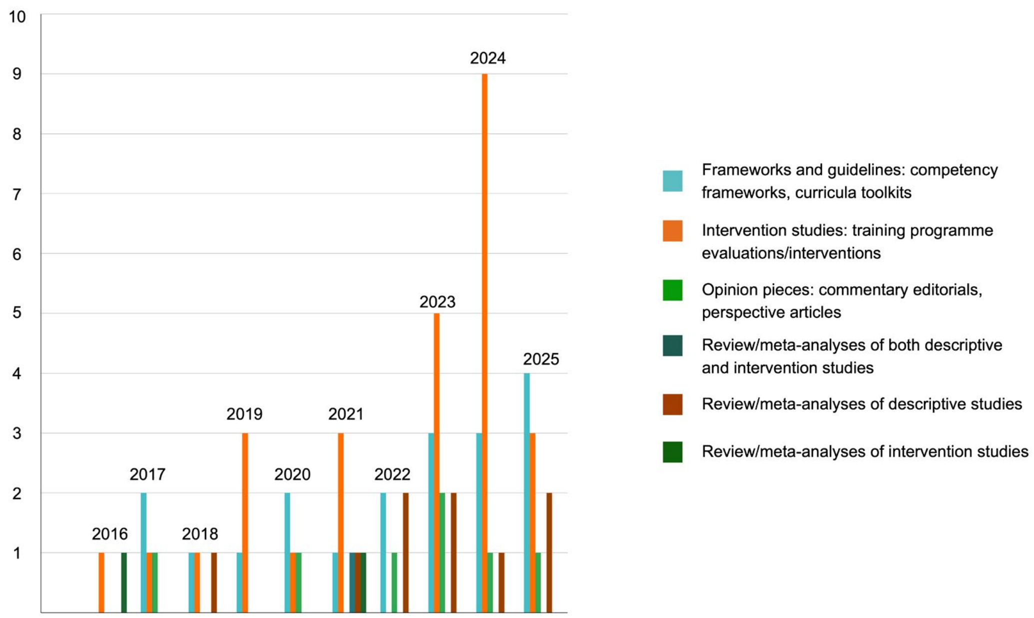


Fig. 10a: Bar chart illustrating study type by year (2015–2025).

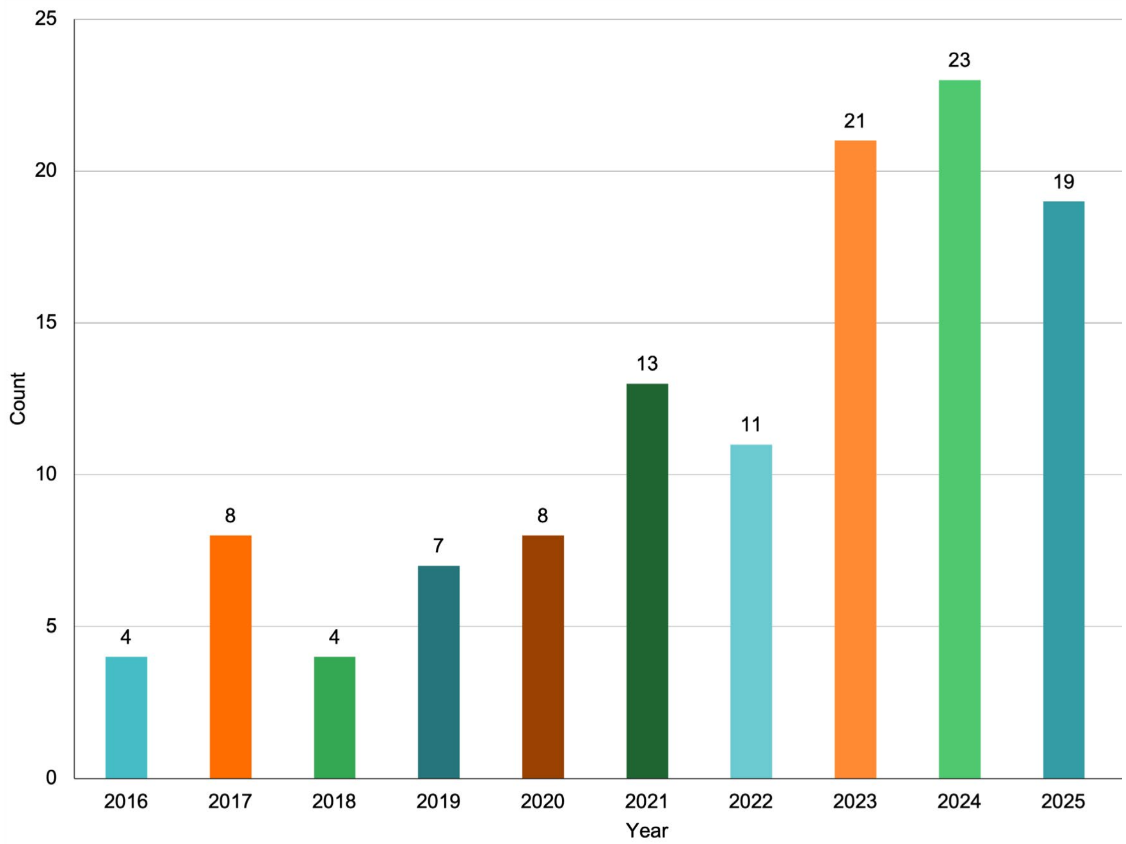


Fig. 10b: Publication volume from 2015–2025 related to health professional education in climate and health.

4.2.3 The evolving climate change and health workforce

The climate and health workforce encompasses all professionals whose roles, decisions and actions directly or indirectly influence population health outcomes in the context of climate change (Fig. 11) (196–198).

As climate change reshapes the landscape of health risks and challenges, the definition of who constitutes the health workforce must expand to reflect the interconnected nature of climate and health systems. Beyond the formal health system workforce, collaboration and engagement with health-determining sectors (in green, in Fig. 11) is required to create integrated approaches that address the root causes of health risk. Beyond these formal professions, broader public understanding of the health impacts of climate change and adaptive responses available to them is clearly also an important enabling factor.[BHAL 16]

BHAL 16: Empowering Thai communities through climate literacy

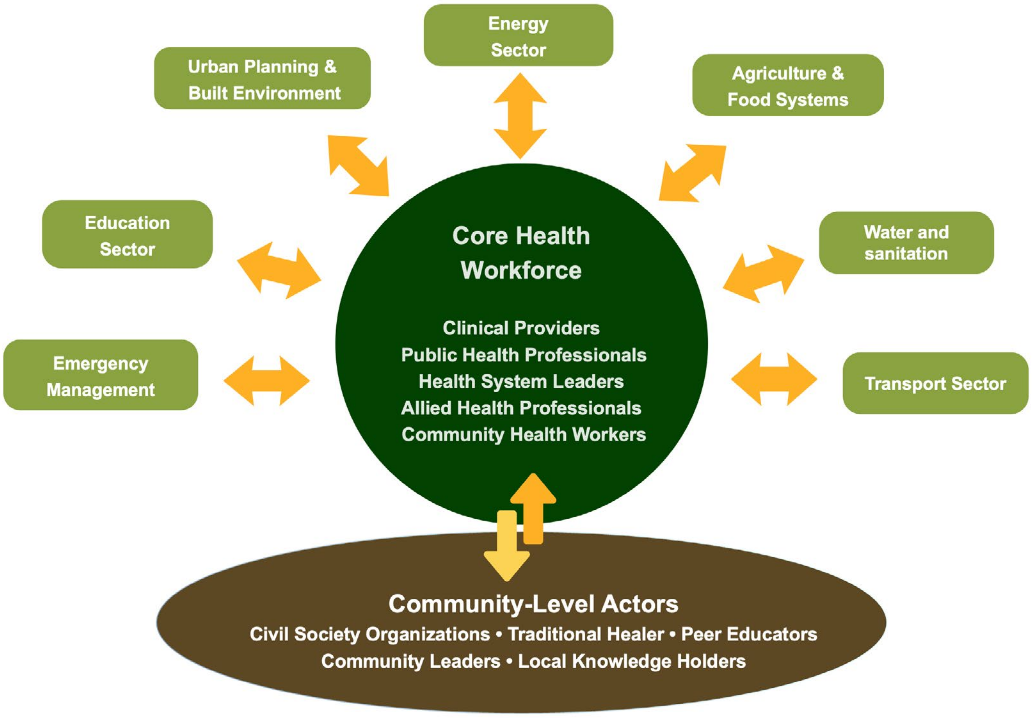


Fig. 11: Dynamic between health-determining sectors, core health workforce and community-level actors.

Roles, responsibilities, and core competencies

Responding effectively to climate change will require health professionals to assume new roles and responsibilities that may not traditionally fall directly within their scope of practice, but for which they are best suited. They will occupy a dual role in the response – both protecting population health directly and catalysing system transformation.

More recently, research has begun to assess the health workforce's perceptions of their own preparedness. Here, health professionals report a sense of professional responsibility to communicate climate-health risks to the public and policy-makers, with patient safety concerns and personal environmental concerns serving as key motivators (199). A growing segment also recognizes the need to mitigate healthcare's environmental impact (200,201). However, self-assessed knowledge of the health impacts remains low (202,203). Despite growing awareness, health professionals consistently identify knowledge gaps, including but not limited to: how climate hazards should be discussed with patients; impacts on clinical practice; and what actions they can take (such as developing climate action plans, early warning systems, and vulnerability assessments) to better prepare their health systems and communities for climate-related health impacts (70,204–206).

Many health professionals and students have also identified the need for education during their professional education and throughout their professional practice, However, barriers to such training exist. These include a lack of time, demotivating environments and inadequate training opportunities (199,200,207,208). These barriers extend beyond clinical healthcare settings to health policy spheres: stakeholders from Brazil, Kenya, the United Kingdom, the United States, the Caribbean, and Germany reported that a lack of skilled personnel knowledgeable about climate and health issues prevents the integration of policy (209).

Over the past decade, several health professional societies and health organizations have produced guidance on climate and planetary health competencies (Table 3). Looking to harmonize this work, the Global Consortium on Climate and Health Education published its third consensus framework in 2025, establishing a shared set of common knowledge, skills, abilities and attitudes necessary for all health professionals (210).

Table 3: Proposed competency frameworks to prepare health professionals to address climate and health adaptation and mitigation challenges

Organization	Document	Year of publication
The Carbon Literacy Trust	Carbon Literacy Standard (211)	2018
Medical Deans of Australia and New Zealand (MDANZ) BHAL 71	Preparing medical graduates for the health effects of climate change: an Australasian collaboration (212)	2018
Canadian Association of Physicians for the Environment (CAPE)	Climate Change Toolkit for Health Professionals (213)	2019
Association for Medical Education in Europe (AMEE)	AMEE Consensus Statement: Planetary health and education for sustainable healthcare (214)	2021
Planetary Health Alliance	Educational Framework (215)	2021
National Health Service (NHS)	Delivering a 'Net Zero' NHS report (216)	2022
European Commission	GreenComp: the European sustainability competence framework (217)	2022
Medical Schools Council	Education for Sustainable Healthcare (218)	2022
The Global Consortium on Climate and Health Education	GCCHE Core Concepts for Health Professionals (210)	2025
Royal College of Physicians	RCP view on healthcare sustainability and climate change (219)	2023
Skills for Health	Global Health Learning outcomes framework (220)	2023
Councils of Deans of Health	Education for sustainable healthcare within UK pre-registration curricula for allied health professions (221)	2023
Pharmacy Declares (endorsed by Pharmacy Schools Council UK)	Environmental Sustainability in Pharmacy Education (222)	2023
Institute of Environmental Management and Assessment (IEMA)	Sustainability Skills Map (223)	2024

BHAL 71: Integrating climate change into medical education

4.2.4 Assessing health workforce capacity by profession

While broad frameworks and competency standards are essential, building a truly climate-ready workforce requires a more nuanced understanding of how different professional groups contribute to adaptation and mitigation.[BHAL 9] Each part of the health workforce faces distinct risks, responsibilities, and capacity needs, and a focus on only one profession will invariably fail.

BHAL 9: Accelerating climate adaptation across NHS Wales

Medicine

Adequately training medical professionals to recognize, prevent and manage conditions linked to climate change is essential for building climate-resilient health systems.[BHAL 42] Yet a significant gap exists: a 2020 survey found that climate change was included in the medical curriculum at only 15% of medical schools globally (224). More recent work from The Global Consortium on Climate and Health Education (GCCHE) across 46 countries demonstrated that the inclusion of climate change in medical curricula was heavily concentrated in high-income countries (225).

Recognition of this educational need has grown substantially among medical students and professionals in recent years. Several national medical school regulatory bodies, including the UK's General Medical Council and the Australian Medical Council, have begun formally recognizing the importance of planetary health in medical curricula (226). The student-led Planetary Health Report Card (PHRC) initiative exemplifies this momentum, with nearly 200 medical schools worldwide participating annually since its launch in 2019. Curriculum scores have risen each year, demonstrating that progress accelerates when formal commitments align with student advocacy.

BHAL 42: Building wellbeing through local action

Nursing

Nurses represent the largest share of the global health workforce, placing them at the forefront of responding to climate-related health threats (227). Evidence shows that nurses are acutely aware of climate impacts on health, including heat-related illness, respiratory conditions linked to air pollution, and disruptions to chronic care during disasters, but many report low levels of preparedness due to limited training opportunities (228,229). Surveys across multiple regions consistently highlight a gap: while nurses express strong motivation to act, they often lack structured curricula, continuing education and institutional support to effectively integrate climate considerations into their practice (228). Broader challenges mirror those seen across health education: many instructors lack climate expertise, curriculum regulators do not consistently emphasize climate integration, and resistance from institutions, citing already overcrowded programmes, often slows adoption.

Nonetheless, countries such as Indonesia and Bhutan have embedded climate change content into nursing education, while professional bodies like the International Council of Nurses advocate for sustainable practices and disaster preparedness training (230–232).

Public Health

In 2024, the GCCHE conducted the first global survey assessing the integration of climate and health education into public health schools' curricula. Of the 279 public health institutions surveyed, 70% reported providing education in climate change and health. However, the survey revealed substantial regional variations in educational integration, with particularly limited formal education in LMICs, the very regions experiencing the most severe climate impacts (233). A separate US-focused study found that only 44 out of the 90 nationally accredited schools of public health evaluated offered a climate change-related course at the graduate level (72).

Allied Health Professionals and Community Health Workers

Together, allied health professionals and community health workers link clinical care with communities and public health programmes. However, across these professions, climate and health training is inconsistent and underdeveloped (194). National and international associations, such as the World Federation of Occupational Therapists, the International Pharmaceutical Federation, and the Royal Pharmaceutical society, are all working to address this directly (234–236). Notably, Liberia's Nationally Determined Contribution (NDC) commits to training and deploying thousands of Community Health Workers by 2030, and some HNAPs explicitly reference community cadres (237). Similarly, Ethiopia's HNAP targets the training of 20 000 community health workers and volunteers to address the health effects of climate change (238).

Health System Leaders and Administrators

Health administration and health policy education is critical to breaking down silos between climate-focused and health-focused sectors and organizations (209).[BHAL 10] While several institutions and initiatives have made substantial strides connecting climate and health data, the capacity within the health sector to use data to inform health system operations and policy requires improvements in training for government officials and policy-makers (209).

For governmental officials and ministries of health, WHO has created multiple climate change and health toolkits with continuing professional education opportunities on early warning systems, vulnerability and adaptation assessments, and monitoring and evaluation guidance (239). Equally, the National University of Singapore has developed an in-depth, yearlong MSc and an Executive Fellowship programme for senior leaders in sustainable healthcare (240).[BHAL 70]

Despite these resources, a lack of knowledge continues to be one of the most commonly cited impediments to both adaptation and mitigation policy among officers of public health.

BHAL 10: Equipping health leaders for climate action

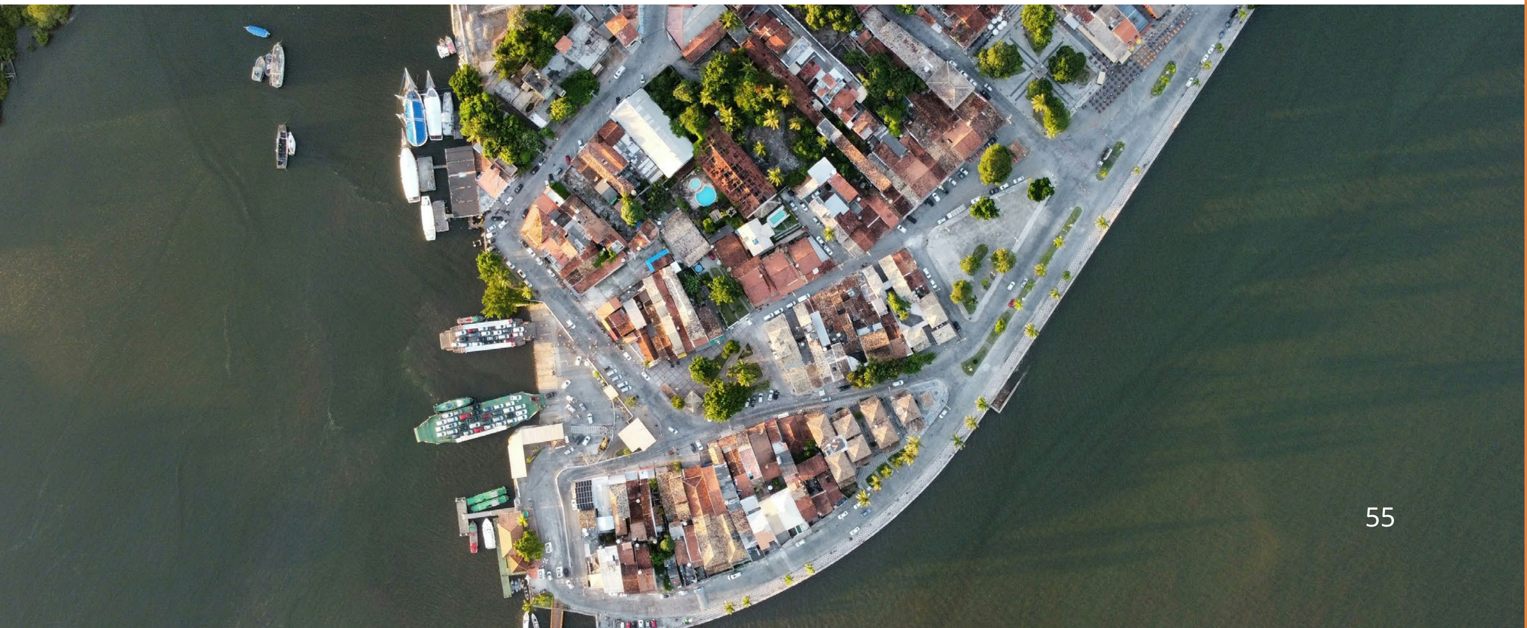
BHAL 70: Empowering the next generation of changemakers

4.2.5 A roadmap to a climate-ready health workforce

Building a climate-prepared health workforce requires a long-term and multilayered approach, whereby countries invest in continuous capacity building at multiple levels, while ensuring that all sectors work in synergy toward shared resilience goals.

The vast majority of the 119 studies captured in the systematic review detailed above focus on nurses and doctors. Despite their central roles, there is significantly less attention paid the capacity development of public health practitioners (12 papers), community health workers (7) and health policy-makers (3). Most of the studies focus on health adaptation, with only 33% integrating both mitigation and adaptation capabilities. The analysis

Photo by Gabriel Martins on Unsplash



also provides the ability to deep-dive into the specific exposures and health outcomes addressed. While studies often had multiple foci, as expected, the most frequently cited exposures were nonspecific climate change (25.1%) and nonspecific climate-related disasters (23.4%), followed by flooding (9.6%), wildfires (8.8%), hurricanes/cyclones/typhoons (8.8%) and extreme heat (8.4%). Health outcomes addressed in the literature (Fig. 12) were similarly broad.

Overall, current training remains oriented toward acute and system-level responses, with slower-onset and chronic health impacts receiving comparatively limited attention.

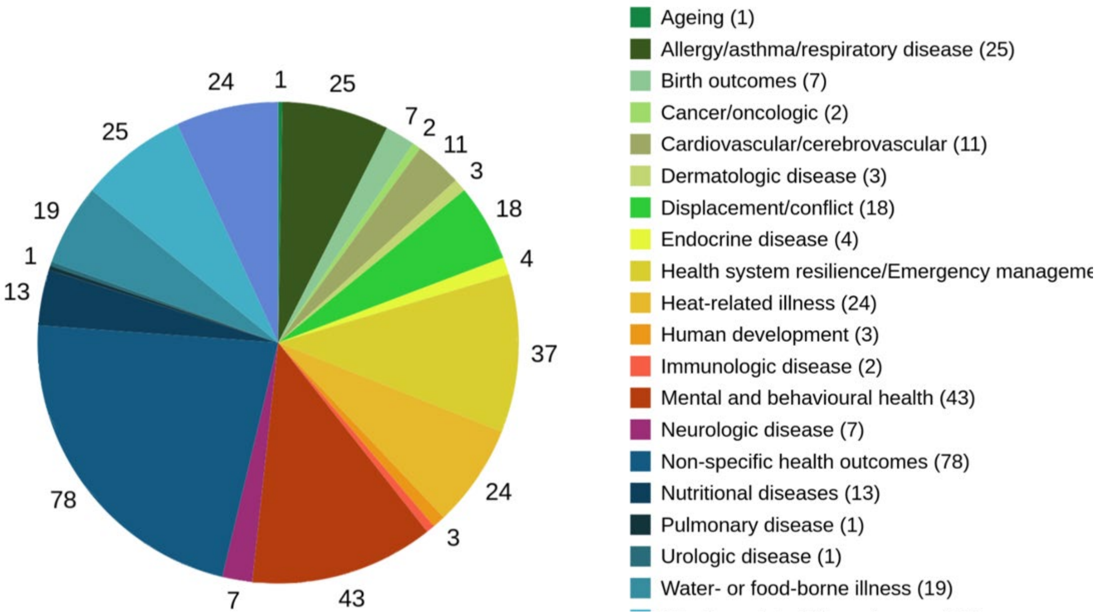


Fig. 12: Frequency of climate-sensitive health impacts addressed across the literature on climate and health workforce education.

Four layers of capacity building are required to prepare the health workforce for climate change.

This work begins with decision-makers and health leaders in the ministries of health, environment, finance and planning. These leaders shape national priorities, allocate resources, and set the tone for institutional action. Programmes like Canada's HealthADAPT and the NHS England Programme illustrate approaches to developing leadership (241,242). Similarly, Yolanda's Law (No. 27.592) in Argentina mandates environmental and climate training for all public officials, embedding climate literacy at the heart of governance (243).

The second level of capacity building focuses on the doctors, nurses, community health workers, and public health professionals on the front lines. These individuals must be equipped not only to identify and treat climate-related health impacts but also to anticipate and prevent them. They are often responsible for delivering the programmes and interventions that actively build community cohesion and resilient capacity.[BHAL 46] The Philippines provides a model through the reforms that followed Typhoon Haiyan, which led to widespread capacity building for health professionals, ensuring that disaster preparedness and health adaptation were institutionalized within health professional training. In parallel, the knowledge, skills, and attitudes needed to address climate change must be embedded within the undergraduate and graduate health professional training programmes (244–247).

The third stage involves engaging professionals in health-determining sectors. Strategies include embedding climate and health content into professional curricula, developing joint continuing education, and establishing intersectoral working groups. Examples include the WHO Basic Training on Environment, Climate Change and Health, focused on environmental science professionals, and the Handbook on Climate Change and WASH developed by the National Water Supply and Sanitation Training Centre of Nepal (248,249). Importantly, work is also needed to ensure the psychosocial resilience of this workforce in the face of climate shocks.[BHAL 41]

The fourth and final level of capacity building lies with civil society: nongovernmental organizations (NGOs), youth groups, community associations, and the wider public that sustain social cohesion and collective action. Civil society has the unique ability to mobilize quickly during crises, to maintain public engagement when political momentum wanes, and to challenge misinformation that undermines public trust.[BHAL 31] Bangladesh, through its Red Crescent volunteers, has demonstrated how civil society can serve as a trusted intermediary between government systems and vulnerable communities, particularly during evacuations and recovery efforts (250).

These four levels form a comprehensive, mutually reinforcing roadmap for climate and health capacity building. Focusing on only one dimension, whether leadership, frontline response, or research, cannot produce lasting results, as informed policy-makers require trained health workers and credible data, while skilled practitioners need supportive policies and functioning communication systems. True resilience emerges when knowledge flows vertically and horizontally across government, science, health services, and society, enabling systems that not only withstand climate shocks but evolve to protect health in a changing world.[BHAL 59]

BHAL 46: Building resilience through data and collaboration

BHAL 41: Caring for Australia's frontline heroes

BHAL 31: Listening to communities for better care

BHAL 59: Building local capacity for climate adaptation in Canada

4.2.6 Critical lessons from a decade of progress

A decade of accelerated engagement from health ministries, health systems, professional bodies, universities and NGOs has yielded remarkable progress in developing the curricula and training infrastructure for a climate-ready health workforce. Seven central conclusions emerge from the literature for all parts of the climate change and health community to consider.

1. **Evidence of effectiveness remains scarce:** The paucity of rigorous intervention studies and systematic reviews limits the ability to identify best practices and scale proven approaches. Comparative effectiveness research remains urgently needed.

2. **A significant gap between awareness and action remains:** Health professionals globally recognize climate change as a serious health threat and express strong motivation to act, yet self-assessed knowledge remains low, and professionals consistently lack practical skills for integrating climate considerations into practice. While isolated progress exists, these examples remain exceptions rather than the norm.

3. **Geographic inequity mirrors climate injustice:** Training initiatives remain concentrated in high-income countries, with this geographic asymmetry perpetuating a knowledge divide where those most affected have least access to capacity-building resources.

4. **Youth-led advocacy drives progress:** Medical and nursing students have emerged as powerful catalysts for change, exemplified by the Planetary Health Report Card initiative covering nearly 200 medical schools. Student demand can create political space for curricular reform when institutional barriers exist.

5. **Reactive rather than proactive training still dominates:** 50% of educational initiatives target already-practicing professionals, while undergraduate curricula remain largely unchanged. This reactive approach creates perpetual skills deficits, requiring continuous catch-up training rather than establishing competencies as foundational knowledge.

6. **Professional hierarchies persist:** Doctors and nurses dominate training initiatives, while community health workers, allied health professionals and policy-makers remain underserved. This imbalance undermines comprehensive health system resilience, as effective climate adaptation requires coordinated capacity across all levels.

7. **Adaptation dominates, mitigation lags:** A minority of educational initiatives address mitigation, focused on the health profession's role in reducing its footprint. This overwhelming emphasis on adaptation means the workforce is being prepared to respond to climate impacts, but not to prevent them.

Taken together, the evidence reveals a rapidly expanding but uneven landscape of workforce development. Progress is strongest where professional associations, regulators, or student networks have driven reform, yet coverage remains patchy, especially in low- and middle-income settings and among community health workers, healthcare administrators, and health-determining sectors. Closing these gaps through equitable investment, coordinated global standards, and sustained national commitment will be essential to ensuring the world's 65 million-strong health workforce is climate-ready.

4.3 Governance and leadership for resilient healthcare

Recommendations

1. **Establish a dedicated unit within the health ministry**

   Every country should designate a senior focal point and a well-resourced team within its ministry of health to coordinate climate and health action. This unit must be empowered to drive both mitigation and adaptation efforts, translate policy into practice, monitor progress, and represent health in national planning and finance decisions.

2. **Institutionalize cross-sector collaboration with a ministerial focal point and engagement with civil society**

   A senior civil servant or ministerial focal point dedicated to cross-sectoral collaboration is often needed to coordinate climate action for the health of the public. Formal mechanisms, such as interministerial committees, linking emissions reduction, adaptation efforts and wider sustainable development under one coherent national strategy. Equally, formal and informal engagement mechanisms with health professionals and civil society organizations help ensure policy and implementation are responsive to the needs of local populations.

3. **Anchor governance in law and accountability**

   Where possible, national climate change and healthcare legislation provides the strongest opportunity to clearly define mandates, responsibilities and reporting requirements, ensuring transparent progress tracking and long-term stability beyond political cycles.

4. **Protect integrity through science and communication**

   Governments and health institutions must strengthen safeguards against misinformation and vested interests from industry or other commercial influence, ensuring that public communication and policy-making are guided by transparent, evidence-based science.

Effective governance and leadership form the connective tissue linking physical infrastructure and workforce capacity to resilient systems. While infrastructure determines what a system can do and the workforce determines how it functions, governance defines who decides, who coordinates, and who is held accountable. In the context of climate change, it determines whether adaptation efforts are coherent across sectors, equitable in impact, and sustained beyond political cycles. It also provides the pivotal link from international processes to national government coordination, right down to local communities, empowering them with the resources and capabilities they need to take action.[BHAL 12]

At a conceptual level, governance refers to the formal and informal systems and structures that enable broader collective action, including policy and implementation towards mitigation and adaptation goals (251). Operating at multiple levels, from the global to the local, governance underpins all actions addressing the health impacts of climate change.

At the international level, it includes instruments such as political mandates, treaties and declarations that establish legally binding and voluntary commitments (39,252). At the national and operational levels, governance provides frameworks, guidance and mechanisms for coordination, reporting and collaboration. As described in Putnam's two-level game, domestic policy pressure or motivation influences what is agreed at an international level, while international governance often shapes or constrains national action (253). This multilevel approach supports effective and relevant action across sectors, systems, geography and scales.

BHAL 12: Localizing health response for resilience in Viet Nam

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This subsection introduces these concepts, the academic evidence, and the state of climate change and health governance across the world. It reviews existing global and national structures, and the future leadership challenges facing health systems.

Given the nature and complexity of governance, high-quality evaluative literature is scarce. As such, this subsection will focus on examples of good governance from across the world, highlighting key successes, failures and lessons learnt.

4.3.1 International governance structures in climate and health

At the international level, governance for climate change and health operates through a network of formal and informal mechanisms that collectively assure ambition, provide coordination and drive accountability. The UNFCCC process provides the overarching political and technical framework, with successive COP presidencies now forming a continuity coalition to ensure that commitments on climate change and health are sustained over time (252). Within the global health architecture, WHO plays a central convening role through ATACH, which now links over 100 countries and partners (6). Technical agencies such as the WHO-WMO joint office provide specialist coordination, and multilateral development banks (MDBs) are becoming increasingly coordinated and scaling up access to finance (149). Finally, civil society and the broader health profession are represented by national and international NGOs such as the Global Climate and Health Alliance (254).

The UNFCCC Paris Agreement explicitly identifies climate change as a "common concern of mankind", emphasizing that when taking climate action it is necessary to "respect, promote and consider" state obligations to "the right to health" (39). Legally binding frameworks provide a high-level, international mandate that sets a clear vision and targets to support cross-sectoral governance, national policies, and actions (255). While health is clearly not the central focus of the UNFCCC negotiations, in many ways its most important role is to provide robust justification for accelerated mitigation and adaptation, taking this mandate and using it to guide national health system resilience and decarbonization efforts. Critically, the UNFCCC process creates adjacent opportunities for climate change and health through the NDCs and the GGA (Box 4).[BHAL 50] NDCs outline a country's short- to medium-term plans for achieving the goals of the Paris Agreement, including mitigation and adaptation (39). The health community has had significant success engaging with these at a national level, with 91% mentioning health and a subset referencing elements of the WHO Operational Framework (Fig. 13) (256). The expectation for increasing ambition means that health-related climate action should become more prominent and specific in each new plan, providing a framework to support more ambitious climate and health action (256). Table 4 summarizes a number of the key governance mechanisms and forums for climate change and health at the international level.

BHAL 50: Integrating health into climate adaptation in Lao PDR

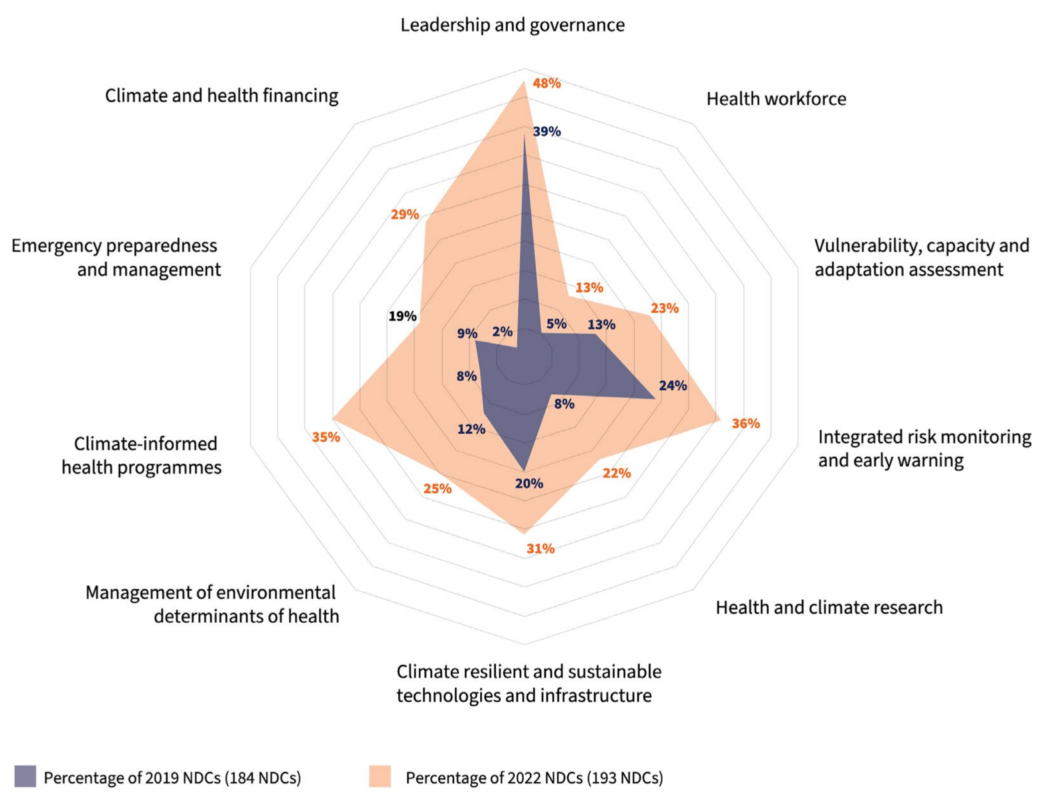

Fig. 13: Percentage of NDCs that included components of the WHO Operational Framework in 2019 and 2022 (256).

Table 4: Selected international governance mechanisms, processes and forums

Year & (Country/ Institution)	Governance Tool (Legal Status)	Description	How it supports governance for climate and health
1988 (UNEP & WMO)	IPCC (Nonbinding)	Provides regular, science-based assessments to support and inform national policies and international climate change negotiations. As an organization of 195 member governments, its reports cover the scientific basis of climate change, its future risks and impacts, and options for adaptation and mitigation.	The Intergovernmental Panel on Climate Change (IPCC) provides authoritative scientific evidence that directly links climate change to health outcomes, helping governments develop evidence-based policies and inform international negotiations.
1992 (UN, Rio Earth Summit)	UNFCCC & the Paris Agreement (Legally binding)	The foundational international treaty that established the global framework for addressing climate change. In 2015, the Paris Agreement was signed, with the stated aim of limiting global temperature rise to well below 2 °C.	It provides the overarching legal and institutional framework for all subsequent international climate action, including the COP meetings and the Paris Agreement. The explicit inclusion of "right to health" secures legal basis for integrating health into climate policy.
2008 (WHO)	WHA Resolution 61.19 & 77.14 (Nonbinding)	Resolution 61.19 was the World Health Assembly's first explicit recognition of the health threats of climate change. In 2024, Resolution 77.14 and WHO's 14th GPW identified "transformative action on climate change and health" as one of the six strategic priorities.	These two resolutions provided the foundation for the WHO Global Plan of Action on Climate Change and Health, adopted at the 78th World Health Assembly (WHA) in May 2025. It provides a strategic framework to guide Member States in building resilient, low-carbon health systems.
2011	GCHA (Nonbinding)	The Global Climate and Health Alliance formally sits as the co-convenor of the WHO Civil Society Working Group on Climate Change and Health.	It acts as the peak international forum for climate change and health professionals at the international level, focused on technical support, coordination, and health advocacy.
2021 (WHO, UK (COP26)	ATACH (Nonbinding)	A voluntary coalition of approximately 100 health ministries, launched at COP26. It serves as a platform for countries to drive progress on climate and health commitments.	Facilitates knowledge sharing and technical support to help countries translate their commitments into concrete actions, operationalizing broader international goals.
2024 (COP26, 27, 28, 29, 30 Presidencies)	COP Presidency Continuity Coalition (Nonbinding)	A coalition uniting past and future COP host countries to ensure health remains central to the global climate agenda. It aims to institutionalize health within the COP process.	It helps to harmonize and synergize existing climate and health initiatives, building on commitments from previous COPs and ensuring sustained momentum across presidencies.
2025 (ICJ)	Advisory Opinion (Legally binding)	Governments have a binding legal obligation under international law to prevent climate harm and protect the well-being of both present and future generations.	The legal obligation to prevent climate harm serves as a powerful tool to compel governments to act on climate change as a public health imperative.
Ongoing	Wider global health architecture (Nonbinding)	Multilateral development banks such as the World Bank, the ADB and the Asian Infrastructure Investment Bank; the WHO-WMO Joint Office; and philanthropic bodies including Wellcome, Rockefeller Foundation and Gates Foundation.	Each in provides technical support, financial resources research and implementation, and critical coordination capacity for the field.
Ongoing	NAPs & HNAPs (Nonbinding)	The process of including specific health-related actions and targets within a country's NAP. This is a primary tool for operationalizing national adaptation to climate change.	It is a crucial mechanism for embedding health into national climate policy, ensuring that a country's adaptation efforts directly address public health risks. It facilitates targeted funding and policy development.

Box 4

Advancements on the Global Goal on Adaptation

Article 7 of the 2015 Paris Agreement established the GGA in an effort to raise the salience of adaptation, providing it with a global anchor equal to the political and finance footing afforded to mitigation and the corresponding temperature targets (41). Put simply, its purpose is to define what success looks like and provide a framework for tracking progress. The Glasgow–Sharm el-Sheikh work programme on the global goal on adaptation was formed to overcome the inherent measurement, reporting and, ultimately, implementation challenges (257).

This process culminated at COP28 with the adoption of the UAE Framework for Global Climate Resilience, which seeks to advance the GGA through 11 targets spanning human health, food, water, ecosystems, infrastructure and livelihoods. It represents the first global consensus on what effective adaptation should achieve and provides a roadmap for coordinated national and international efforts. Across these developments, health has emerged as a core pillar of the GGA, offering a unifying platform around which health adaptation can coalesce at the international level. Following COP28, a suite of technical experts have been preparing a suite of indicators corresponding to each target, to be adopted by Parties at COP30 (41).

The overall process provides an excellent example of the importance of coordinated health community engagement. In isolation, each technical contribution or step in the negotiation process seems incremental. However, together, the greater arc reveals a coherent and influential agenda that positions health not as a peripheral beneficiary of adaptation, but as one of its defining measures of success.

4.3.2 Health system adaptation, governance and leadership

While international frameworks facilitate global cooperation and information sharing, the development of a national governance structure tailored to each country's unique context is clearly the primary determining factor in advancing action on climate change (258).

There is no one-size-fits-all solution, as countries face varying institutional arrangements, vulnerabilities to climate change, and capacities to respond. An ideal national governance structure is integrated, adaptive, and inclusive, prioritizing a whole-of-government and whole-of-society approach (258,259).[BHAL 53] In many countries, a strong legal and institutional foundation, such as a national climate change act, serves as an anchor that provides impetus and long-term stability, as well as clear mandates, roles and responsibilities across various ministries and sectors (260). Given the nature of the change being asked of health systems, progress at sufficient pace and scale will be difficult, if not impossible, without a focal point and a dedicated team working on climate change within the health ministry.

BHAL 53: Building cross-sectoral health system sustainability

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This provides a central unit to coordinate activities, develop policies and drive implementation. Reassuringly, the 2021 WHO Country Survey suggests that 85% of countries have a designated focal point (140). However, this work must go further, and the establishment of a formal and dedicated Climate and Health Unit within ministries of health is clearly necessary. Where possible, these team should be sufficiently senior and directly represented on the governing structures of the health ministry.[BHAL 7]

Beyond a strong legal base and dedicated team, effective governance relies on robust coordination mechanisms. Cross-government committees, for instance, can facilitate collaboration between health, environment, energy, finance and transport ministries to maximize synergies and prevent conflicting policies (14). Furthermore, intragovernmental coordination between national, subnational and local governments is important to ensure that policies are effectively implemented and tailored to meet the specific needs of local communities (258).

National governance strategies with strong support in the literature are summarized in Table 5.

BHAL 7: Institutionalizing climate action in health in the Philippines

Table 5: Select strategies to support national climate and health governance (14,259)

Strategy	Detail	Example
Strengthen legal frameworks and ensure national capacity BHAL 60	• Ensure the inclusion of climate and health priorities in national legislation, such as a Climate Change Act of Healthcare Act. • Establish or expand institutional structures like a Climate and Health Unit within the ministry of health to coordinate efforts and drive action.	**Fiji** launched a Climate Change and Health Strategic Action Plan that included an activity to "establish and empower the Climate Change and Health Unit" (261). The **UK Health and Care Act of 2022** placed new duties on all NHS Trusts to meet the national commitments to net zero care (262).
Enhance multisectoral collaboration	• Build partnerships across ministries to integrate health considerations into climate policies and vice versa. • Participate actively in interministerial committees or national climate coordination bodies to ensure health is prioritized in broader climate strategies.	**Colombia's Intersectoral Commission on Climate Change (CICC)** is a national body that brings together representatives from various ministries, including the Ministry of Health. It supports national climate policies and plans (such as NDCs) to be developed with a whole-of-government approach (263).
Develop clear governance mechanisms	• Create coordination mechanisms, such as working groups or steering committees, with defined roles, responsibilities, and accountability. • Ensure regular communication and reporting between national, subnational and local governments to align policies and implementation.	**New Zealand's HNAP** includes the establishment of a scientific advisory group in climate and health to guide the work programme. This group will ensure adaptation planning is informed by high-quality research and will help shape further actions. BHAL 14
Focus on evidence-informed policymaking	• Invest in climate-smart health information systems to collect, analyse, and share relevant information. • Use V&A assessments to identify risks and inform targeted interventions. • Convene wide technical expertise. BHAL 66	The **European Union** has created the **European Climate and Health Observatory**, a partnership between the European Commission, the European Environment Agency and others, to provide access to information and tools adapt to the impacts of climate change.
Leadership and advocacy	• Identify high-level champions within the government to advocate for climate-health priorities and secure political support. • Build capacity among policy-makers and health leaders to understand and act on climate-health challenges.	In many countries, the Minister of Health or another high-level official may serve as a champion for climate and health issues. In May 2022, **G7 health ministers** announced their commitment "to build sustainable and climate-neutral health systems at the latest by 2050" (264).
Secure sustainable financing	• Align health adaptation goals with national budgets and explore international funding opportunities, such as multilateral development banks or climate finance mechanisms.	The **Federated States of Micronesia** secured funding from the **GCF** for a project to increase the resilience of its health system to the risks of climate change (265).
Monitor, evaluate, and learn	• Establish frameworks for monitoring and evaluating progress on climate-health policies. • Share lessons learned and best practices through regional networks.	**California's state government** developed a Technical Advisory Council to support planning efforts, complemented by a state Climate Action Team. The team coordinates responses across the state (266).

BHAL 60: Building Georgia's roadmap for climate resilience

BHAL 14: New Zealand's path to climate-ready health

BHAL 66: Advancing multisectoral leadership for climate resilience

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4.3.3 Key challenges to effective governance

Having explored the international governance architecture and the evidence surrounding good national governance for health adaptation, it is also important to consider the primary barriers and challenges to progress. Three stand out in this emerging field: a shifting global context; inadequate resource relative to the scale of the challenge; and direct challenges from vested interests.

A changing global context

Governance systems and structures exist to ensure accountability, coordination and stability as health systems address the resilience and mitigation imperatives that climate change brings. Current efforts remain insufficient, amplifying risks and rendering global targets and commitments increasingly difficult to achieve.

Countries that face disproportionate impacts from climate change often demonstrate high political will and leadership but are limited in their national implementation capacity and global leverage (267). Historically, high-emitting countries hold much of the power and responsibility to act, yet lack the urgency to do so as their economies remain tied to carbon-intensive industries (268). The rise of rapidly emerging economies through Asia and the impressive decarbonization efforts seen across most of Europe are changing this picture.

Despite growing political will to prioritise the climate and health agenda, demonstrated by 151 countries signing the COP28 Declaration on Climate and Health, significant gaps remain in translating these global commitments into action at a national level (269). Amid economic uncertainty and conflict, global politics is trending towards nationalism, with funds withdrawn, national interests prioritized, and countries seeking a comparative advantage in resources, technology and profit (270). This reflects an ongoing perceived tension between economic growth and the need for environmental protection and social justice (271). Short-term political and economic priorities often come at the expense of our health, well-being and planetary sustainability, diffusing responsibility and delaying meaningful collective action (272). National bipartisan support for climate action can counter short-termism, increase political action, and enable long-term planning and investment in governance to further drive change (273).

Financing for health

At the global level, nations agreed at COP29 to establish the New Quantified Collective Goal (NCQG), pledging at least US$ 300 billion each year through provision and mobilization. Contributions to the Loss and Damage Fund remain inadequate, with only US$ 789 million pledged as of June 2025 (274,275). Further complicating the system, existing financing mechanisms are opaque, fragmented, and administratively heavy, making them particularly difficult to access for most climate-impacted countries (61). As an example, in 2023, 59 LDCs and SIDS countries each spent more on debt repayments than they received in climate financing (276). This will be discussed in more detail in the subsection on financing.

Combating vested interests

As of 2024, oil and gas firms were on track to exceed a 1.5 °C-compatible pathway by 189% by 2040, while governments provided US$ 7 trillion in fossil fuel subsidies in 2022 (63,277). Misinformation, disinformation, and greenwashing further erode public trust and polarize support (276). Climate litigation has emerged as an effective tool for enforcing responsibility, exemplified by the 2025 ICJ Advisory Opinion (10). Strengthening mechanisms such as the Fossil Fuel Non-Proliferation Treaty and conflict-of-interest reporting could improve accountability (42,278).

As the climate and health field has grown in influence, it has naturally attracted increasing engagement from industries across healthcare (including the pharmaceutical and medical device industries). While collaboration can accelerate innovation and scale, there are critical lessons to be learnt from the commercial determinants of health field surrounding the acceptance of funds, the use of cobranding and sponsorship, and the participation of commercial actors in the policy and technical forums that shape the global agenda.

Ultimately, countering these vested interests requires strengthened conflict of interest policy applicable to all forums, and a concerted effort from the health community to champion evidence-based policy and clear, science-driven communication. Health professionals have a unique ability and responsibility to translate complex climate change science into trusted public health narratives, ensuring that decision-making is guided by evidence rather than influence (279).

4.3.4 Conclusion

Effective governance and leadership are the foundation of climate-resilient health systems. Across every level, from global coordination to national implementation, clear mandates, accountable institutions and trusted leadership determine whether ambition translates into sustained action. This requires coordination not just national governments, but enhanced governance from all hospitals, clinics and health actors.[BHAL 47]

As countries navigate competing political and economic pressures, strong governance ensures coherence between mitigation and adaptation, protects integrity from vested interests, and anchors decision-making in science, equity and long-term vision. Ultimately, resilient health systems will depend as much on the quality of their leadership and governance as on the resources they command.

BHAL 47: Embedding sustainability into quality healthcare

4.4 Climate adaptation funding for health

Recommendations

1. **Commit to predictable and scaled investment in health adaptation**

   Parties and financing institutions should establish clear, health-explicit targets within adaptation portfolios. Current evidence suggests that supporting health-relevant adaptation at a level equivalent to 7% of total adaptation financing needs would meet the estimated US$ 22 billion required annually.

2. **Make access simpler and faster**

   Lengthy approval processes and complex reporting requirements continue to delay implementation. Expanding readiness support, standardizing proposal templates, and offering preapproved models for common interventions such as climate-resilient facilities or heat–health action plans would help countries move from planning to delivery.

3. **Improve visibility and accountability of health within adaptation finance**

   A shared tagging and reporting approach across multilateral funds and development banks would allow health components to be identified, tracked and evaluated within wider climate programmes, while avoiding double-counting. Making health visible is an essential prerequisite for mobilizing new partners and sustaining investment.

4. **Continue to strengthen the underlying evidence base**

   The Belém Health Action Plan highlights a critical gap in data, with significant new research required focused on high-impact and high-value interventions. Developing common evaluation criteria, methods, and metrics to measure health adaptation interventions, and supporting independent evaluation of funded projects will allow future decisions to be guided by robust evidence.

4.4.1 Financing transformative adaptation in health systems

Access to adequate and sustained finance is critical to every dimension of the Belém Health Action Plan. Capital investment is required to build resilient infrastructure; new workforce capacity and capability needs time and adequate resourcing; and sourcing and allocating funding effectively is one of the most important functions of national leadership and governance. Without explicit, ringfenced and additional finance, commitments to climate-resilient health systems risk remaining rhetorical. It is therefore both a final enabling function and a cross-cutting determinant of success.

Despite its importance, the evidence base on health adaptation financing remains thin, with few high-quality peer-reviewed papers that address the topic. As has been stated previously, only a limited number of health adaptation interventions have been both implemented and then rigorously and independently evaluated at scale, meaning that cost–benefit and cost–effectiveness analysis is often lacking. While this is changing (Box 2, Box 5), for now, most of the information that does exist comes instead from governments, UN agencies and multilateral development banks.

This subsection draws primarily on official reporting and donor analyses to examine three questions: how current climate and health financing is structured; where the key gaps and inequities lie; and what opportunities exist to build a more coherent, evidence-based and just financial architecture for health adaptation and resilience. It primarily focuses on the provision of development financing to low- and middle-income countries, rather than national sources of adaptation funding from high-income countries.

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4.4.2 Funding sources for climate-resilient healthcare

Over the past two decades, climate adaptation funding has become a focus of multilateral and national investment strategies. In the early 2000s, adaptation was largely overshadowed by mitigation, with most finance directed toward renewable energy projects and emissions reduction (280). The establishment of the Adaptation Fund under the Kyoto Protocol, and later the Green Climate Fund under the 2015 Paris Agreement, provided dedicated vehicles for channelling resources toward adaptation and resilience (39,281). Since then, donor pledges have steadily increased, with adaptation gaining more balanced attention alongside mitigation in both international negotiations and domestic climate strategies. Recent studies suggest adaptation finance is still insufficient relative to global needs, but the trend reflects steady institutionalization of adaptation finance and delivery to the country-level operators (282,283).

The NCQG, agreed at COP29 in Baku, continues to be the source of much political contention. At US$ 300 billion in annual climate flows by 2035 for all of mitigation and adaptation, it triples annual amount previously committed to in the 2010 Cancun Agreement (275). However, this must be placed in context, with the High-Level Expert Group on Climate Finance (an independent commission of experts, secretariated by the London School of Economics and Political Science) providing a significantly higher estimate of US$ 2.3–2.5 trillion in annual mitigation and adaptation financing required for LMICs (excluding China) (284).

Focusing specifically on adaptation, the 2025 Adaptation Gap Report places the total annual cost of adaptation alone in 2035 at approximately US$ 310–365 billion for non-Annex 1 countries (including China) (285). Again, by comparison, the High-Level Expert Group on Climate Finance estimates are significantly higher, suggesting an annual adaptation cost of US$ 250 billion for all LMICs (excluding China) (284). The complexities here (differences in assessment years, country inclusions and exclusions, underlying analytical assumptions about inflation and economic growth) underscore the difficulty in such calculations. Interestingly, sensitivity analysis suggests a less than 10% variation depending on climate projections (RCP 2.6–6.0) due to the near-term nature of the estimates (286).

Regardless of the total funding requirement, the total amount of deployed funding today is clearly insufficient. Total international public adaptation finance flows from HICs to LMICs was US$ 28 billion in 2022, falling to US$ 26 billion in 2023 (the latest available year for which comprehensive data are available), underscoring the tremendous magnitude of the financing gap (Fig. 14) (285,287).

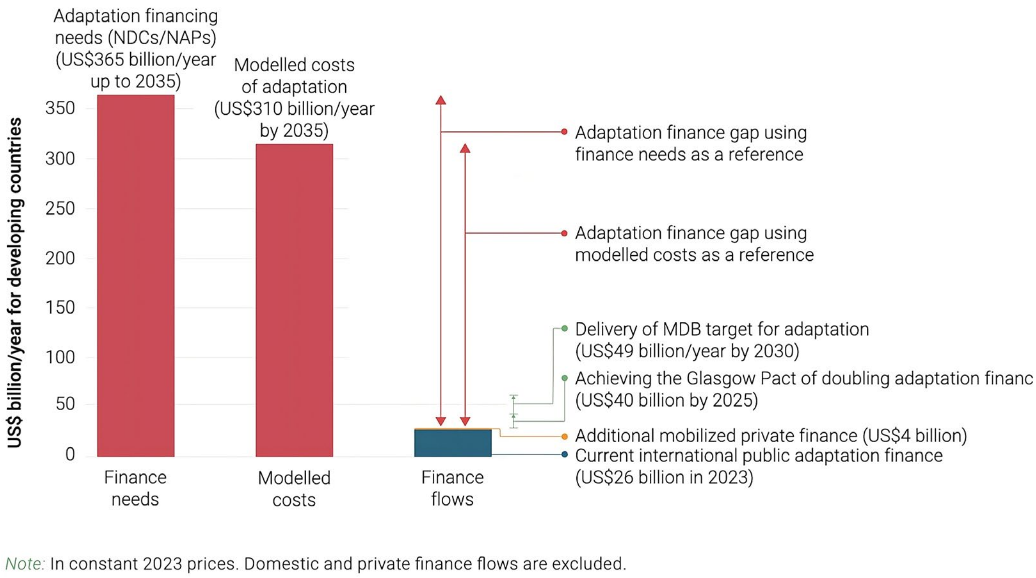

Fig. 14: Adaptation funding requirements (finance needs, extrapolated from submitted NDCs and NAPs), global modelled costs, and current financial flows (285).

Broader adaptation financing

The Green Climate Fund, the most significant dedicated contributor to adaptation financing, committed approximately US$ 2.1 billion to new climate projects in 2023 and US$ 2.5 billion in 2024, with just over half of this going to adaptation measures (288). The Adaptation Fund is a separate entity set up under the Kyoto Protocol, which has allocated more than US$ 1.3 billion to adaptation activities across its lifetime (289). The Global Environment Facility (GEF) supports adaptation to climate change in developing countries through the Least Developed Countries Fund (LDCF), which supports urgent, medium-, and long-term adaptation needs in LDCs, and the Special Climate Change Fund (SCCF), having disbursed approximately US$ 2.5 billion for adaptation across all sectors for 524 adaptation projects since the funds' inception in 2001 (290). The World Bank, a longstanding actor in climate finance, reports having provided US$ 10.3 billion in adaptation-related financing in FY2024, though precise attributions to health are complex and difficult to track (291,292).

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Bilateral flows are also significant. The European Union and its member states provided more than US$ 33 billion of international public climate finance in 2023, more than half of which was focused on adaptation (293,294). The United Kingdom's Foreign, Commonwealth, and Development Office (FCDO) has also played a significant role in health adaptation, providing support for in-country resilience and for international partnerships such as ATACH (295). BHAL 72

BHAL 72: Driving climate-health resilience through financing

Global adaptation financing for health

The 2025 Adaptation Gap Report builds on its 2023 Adaptation Finance Gap model, estimating that approximately US$ 22 billion per year is required by the health sector in non-Annex 1 countries to adapt to the effects of climate change in 2035 (under RCP4.5) – roughly 7% of the total need across all sectors (285,296).

Analysing and tagging the above funding commitments specifically to the health sector is often difficult and commonly results in accounting errors (double, under, or over).

The Lancet Countdown tracks spending on adaptation for health and health-related activities over time, with estimates derived from private and public datasets which track and triangulate financial transactions from insurance companies, the financial sector, and multilateral climate finance. Best estimates suggest that health adaptation funding has been increasing as a proportion of overall funding: 4.6% (2016), 5% in 2018, and 5.6% from 2019 to 2021 (297). Other estimates provide some validation to this, with an estimated 4% of implemented multilateral development bank adaptation funding allocated to health across a similar period (2019-2023) (285).

One attempt at calculating the investment suggests that self-reported funding commitments of US$ 7.1 billion worth of health and climate financing were made in 2022. These came from bilateral donors (US$ 4.8 billion), multilateral health funds such as the GCF (US$ 1.5 billion), and philanthropic organizations (US$ 160 million) (61). In addition to this direct health sector support, over US$ 13.5 billion has been provided annually for activities in health-determining sectors such as agriculture. Of all of these, the most clearly understood international funder of health adaptation is the Green Climate Fund, which has invested a total of US$ 764 million between 2021 and 2023 (US$ 178 million in 2021, US$ 164 million in 2022, US$ 422 million in 2023), a 137% increase over that period (298,299).

As the field has evolved, new funding sources have opened, including more substantial engagement from multilateral development banks such as the ADB (Box 5) and philanthropy. The latter has been particularly impactful in empowering the health and climate change community, with strong and active portfolios focused on innovation, research, and policy change. Wellcome's dedicated Climate and Health programme provided US$ 176 million for ecosystem building, advancing science and delivering impact in the 2023/24 financial year alone (300). The Rockefeller Foundation also committed US$ 100 million to test and scale climate and health solutions globally at COP28 in 2023, and joined a US$ 50 million Adaptation and Resilience Fund partnership led by the ClimateWorks Foundation to support locally led solutions for climate risks in 2025 (301,302). The Gates Foundation has committed US$ 40 million to the Climate and Health Catalytic Fund at the Global Fund to accelerate action on the health impacts of climate change and build climate-resilient health systems (303). This sustained philanthropic engagement is particularly important for supporting primary scientific research and bridging the gap to implementation.

Box 5

Mobilising Climate Finance for Health: The ADB's Climate and Health Initiative

The ADB has made climate action a central financing priority, committing US$ 100 billion from 2019–2030 and targeting 50% of annual investments for climate-related activities by 2030 (304).

The ADB Climate and Health Initiative (CHI) was launched at COP28 to integrate initiatives from across the bank. Guided by the 2023 High-Level Principles for Health Care Climate Action (developed by the ADB and the G20 under India's Presidency), the CHI exists to (305):

- Improve knowledge and evidence of the gender-differentiated health impacts of climate change and the most effective strategies to strengthen climate resilience within health systems;
- Build institutional capacity to design and implement innovative, evidence-based gender-responsive climate and health solutions; and
- Develop a pipeline of transformative investments that will strengthen climate-resilient and low-carbon health systems.

To date, the CHI has directly supported 29 member countries across urban heat and health mapping, resilient infrastructure design, project preparation, development of HNAPs, inclusion of health in NDCs, and mitigation planning.

Across its entire 2024 portfolio, ADB-supported projects have improved the well-being of 23 million people through stronger health, education, and social protection systems, and saved 50 million tonnes CO_2e in annual emissions (306).

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The health adaptation funding landscape

Multilateral climate funds are dedicated financing vehicles established under international agreements to support developing countries in addressing climate change. Prominent examples include the GCF, the Adaptation Fund (AF) and the GEF (288,307). These funds channel resources from multiple donor governments and disburse through grants, concessional loans that offer rates which are more favourable than the open market, and results-based finance mechanisms (RBF) for predetermined outcomes.

Multilateral development banks such as the World Bank, the African Development Bank, the ADB, the Asian Infrastructure Investment Bank and the Inter-American Development Bank provide significant financing for climate adaptation. MDBs often leverage their large capital base to provide concessional or market-based loans, technical assistance and blended finance solutions. Increasingly, MDBs are integrating climate resilience into health infrastructure projects, health system strengthening programmes and social protection schemes (292).

UN agencies play a unique role in channelling adaptation finance, often focusing on technical assistance, policy support and programme implementation. WHO, the UN Development Programme (UNDP) and the UN Environment Programme (UNEP) have been instrumental in supporting countries to integrate climate resilience into health strategies and national adaptation plans. While they are not typically direct funders, they serve as implementing entities for climate funds and conveners of global knowledge and capacity-building (308).

Government development agencies key providers of climate adaptation finance, either through direct project funding or by contributing to multilateral climate funds. Agencies such as the UK FCDO, German Agency for International Cooperation (GIZ), the Norwegian Agency for Development Cooperation (NORAD) and Agence Française de Développement (AFD) fund health adaptation projects globally (283).

Philanthropic foundations provide flexible and often catalytic financing for climate and health adaptation. Examples include Wellcome, which has prioritized climate and health research; and the Rockefeller Foundation, which has supported resilience-building initiatives in cities and communities. Foundations often fill gaps left by public finance by funding innovation, pilot programmes, and advocacy (61,300).

Geographically, finance is primarily mobilized from high-income countries consistent with obligations under the UNFCCC and reaffirmed in the Paris Agreement. The European Union and its member states are collectively the largest providers of international public climate finance, followed by individual countries such as Germany, France, the United Kingdom, and the Nordic countries (283). The United States has also played a major role, though its contributions have varied depending on political leadership and budgetary priorities. Outside of Europe and North America, Japan, Australia, and the Republic of Korea provide significant bilateral finance, particularly through development agencies and contributions to multilateral climate funds (282).

Funding from multilateral channels that pool contributions from donor countries are headquartered in Asia, Europe, or the United States, but disburse globally (281). Recent analyses show that although developed countries remain the dominant source of finance, cooperation between LMICs, with countries including China, Brazil, and India beginning to provide adaptation support, often regionally or through multilateral development banks.

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4.4.3 Putting health adaptation financing to use

Spending priorities in adaptation finance mirror the core functions of health systems covered in the earlier sections of this Special Report. These include climate risk assessment and planning, disease surveillance and early warning, resilient infrastructure and energy systems, supply chain security, workforce training, community-based adaptation, and the continuity of essential services during shocks (42). Each function requires adaptation measures, and funding often flows along these same lines. Programs focused on infrastructure resilience strengthen hospitals and clinics to withstand extreme heat, flooding or cyclones, retrofit buildings, reinforce energy systems, and integrate renewable power for continuity of care. Parallel investments target surveillance and information systems, embedding meteorological and environmental data into decision support and epidemic forecasting.

The use of funds also reflects different layers of governance and scale. National-level allocations tend to emphasize systemwide functions: policy development, vulnerability and risk assessments, surveillance and laboratory systems, pharmaceuticals and supply chains, and the integration of health within national adaptation plans or NDCs. Subnational and municipal channels, by contrast, tend to finance direct service delivery and facility-level resilience, such as retrofitting clinics, upgrading cooling and backup power systems, developing emergency operations centres and implementing climate-smart procurement and logistics (14,292). An overview of the health adaptation interventions requiring funding and corresponding capital pressures is provided in Table 6.

Table 6: Capital intensity of health adaptation interventions

Components of health systems requiring adaptation finance	Type(s) of adaptations	Capital intensity
Governance, planning & risk assessment	Institutional strengthening, climate-risk mainstreaming, policy & planning, data & diagnostics	Medium
Surveillance & early warning	Climate-integrated surveillance, One Health data systems, forecasting models, data infrastructure	Medium
Infrastructure & energy resilience	Facility retrofits, renewable energy, floodproofing, resilient design standards	High
Supply chain & logistics	Climate-resilient procurement, cold chain reliability, transport redundancy, buffer stocks	High
Health workforce & workforce training	Training on climate risks, emergency response protocols, capacity building	Low to Medium
Community-based adaptation & outreach	Community health adaptation, behaviour change, local resilience programmes	Low to Medium
Service delivery continuity during shocks	Emergency operations centres, backup power, mobile clinics, flexible service models	Medium to High
Health information systems & digital health	Integration of climate data, decision support, early warning dashboards, interoperability	Medium

At the project level, climate funds commonly approve multi-million-dollar grants for single countries and larger packages for regional activities. MDB operations can range from tens to hundreds of millions depending on country size, fiscal capacity, and scope (infrastructure versus systems strengthening), though often health adaptation funding is a subset of a larger award.

4.4.4 Types of adaptation funding available

The range of funding mechanisms available is diverse, ranging from grants, concessional loans, and guarantees through to equity, results-based finance and blended finance that crowds in private capital.

Grants remain the most common and accessible form of adaptation finance for health. They fund public goods functions that rarely generate direct financial returns, but are foundational to resilience, such as national risk assessments, surveillance and data systems, emergency preparedness and workforce training. Grants also support NGOs and multilateral programmes that work at the interface of climate, environment and health. In recent years, foundations and individual philanthropies have expanded this space, financing pilot interventions, early research and advocacy efforts that help establish the evidence base for later investment.

Concessional and market-rate loans are used primarily for capital-intensive adaptation measures, such as facility retrofits, infrastructure, supply chain modernization, and digital and data systems to improve continuity of care. Concessional terms, such as below-market interest rates, extended maturities or grace periods, enable borrowing countries to invest in resilience without exacerbating debt distress. The MDBs and bilateral agencies deploy instruments like these, often through health or climate investment windows. Where concessional lending is paired with technical assistance and robust monitoring frameworks, it can unlock significant cofinancing from domestic budgets or private partners (309). Given the often infrastructure-related components of these programmes, funding tends to be higher, often in the US$ 50–200 million range.

Guarantees and insurance instruments function as risk-sharing tools to encourage private investment in climate-resilient health infrastructure and services. By absorbing or transferring a portion of project risk through partial credit guarantees, political risk insurance, or catastrophe-linked coverage, funders can make adaptation projects "bankable". These instruments are increasingly used to back investments in renewable energy for hospitals, resilient logistics networks and cold chain infrastructure (310).

Equity, venture and impact capital represent an emerging class of adaptation finance particularly relevant to innovation and technology development. Mission-aligned investors, impact funds and venture philanthropies deploy "patient capital" to early-stage enterprises working on climate-resilient health solutions, ranging from remote patient monitoring for heat-related illness to climate-smart cooling and environmental analytics that anticipate disease outbreaks. Unlike grants or loans, equity investments seek both social impact and financial return, often serving as a bridge between proof-of-concept and market deployment. Though still a small share of total adaptation finance, this category is critical for building the innovation pipeline and crowding in commercial participation.

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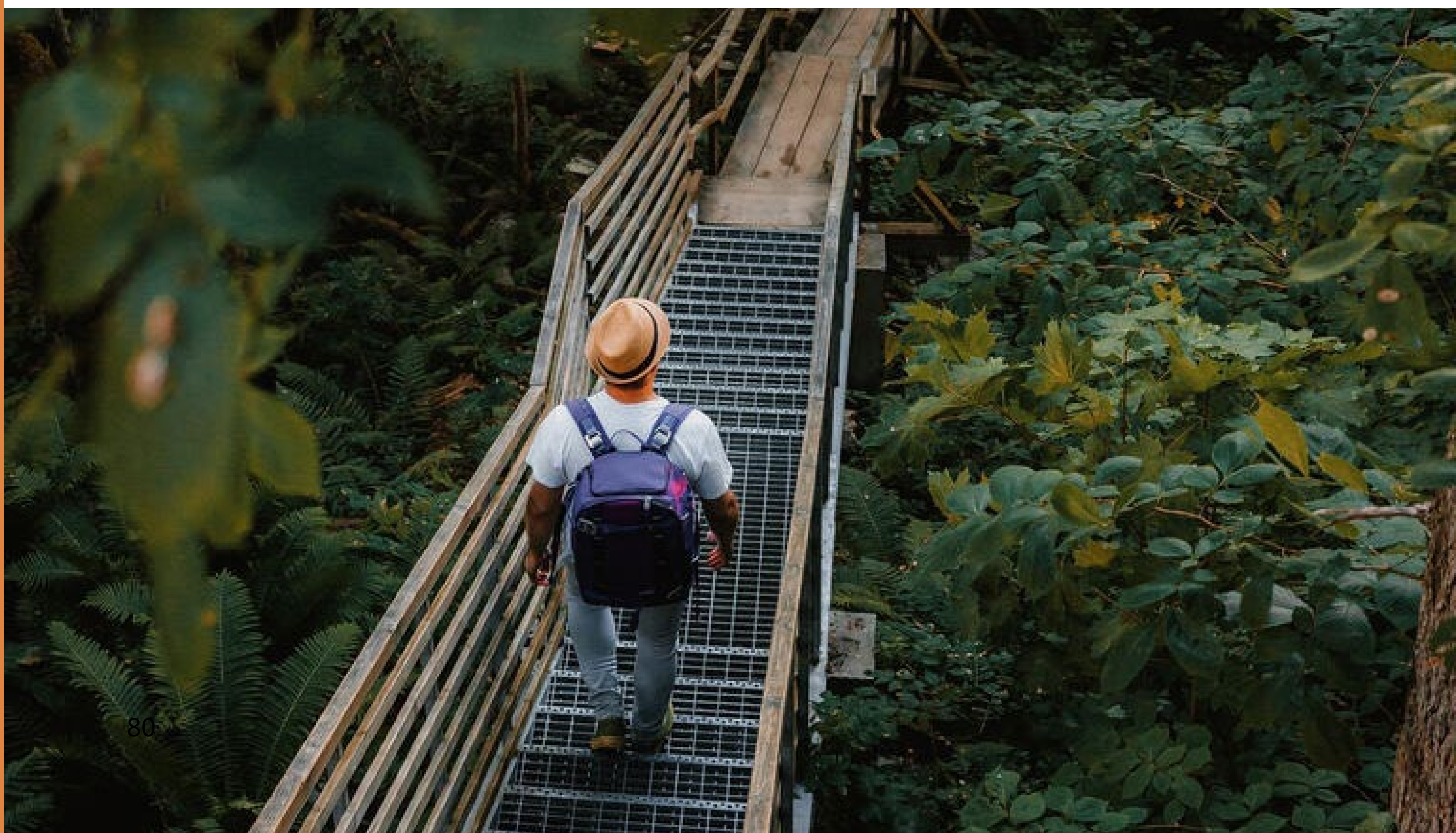

Results-based finance, or pay-for-performance, links disbursements to verified outcomes such as the continuity of essential health services during climate events, reductions in disease incidence, or the achievement of facility-level resilience standards (311). By shifting focus from inputs to outcomes, RBF creates incentives for efficient and accountable implementation. In the health sector, the World Bank's Program-for-Results (PforR) and GCF's results-based adaptation pilots demonstrate how this model can improve both transparency and sustainability (312,313).

In practice, *hybrid and blended structures* are common. A single adaptation programme may use grant funding for technical design and capacity-building, concessional funding for capital expenditures, and guarantees to mobilize private co-investment in infrastructure or services (314). This approach to layering reflects both the complexity of climate change and health challenges and the necessity of leveraging multiple financial instruments to achieve scale.

4.4.5 The future of climate adaptation funding for health

Previous narratives suggesting that there was little-to-no climate financing available for health and healthcare are no longer accurate. With over US$ 7.1 billion provided in 2022, the health sector is beginning to receive the attention it requires (61). Now, with dedicated health and climate teams from many of the multilateral development banks and major bilateral donors, momentum is growing.

Yet, the scale of resources remains far below what is required to protect population health in a rapidly heating world. Available finance is still below that required for health adaptation, and much of what is available is fragmented, short-term and inaccessible to those most in need.

The Belém Health Action Plan provides the coordination and sharpened evidence base needed to guide investment toward interventions with demonstrable benefit. Continued growth will depend not only on political commitment but also on closing the evidence gap, improving tracking systems and ensuring that finance is directed towards what works.

Innovation, research and evaluation

Photo by William Felipe Seccon on Unsplash

Recommendations

1. **Rebalance the research agenda towards equity and implementation**

   The existing literature is disproportionately concentrated in high-income countries and largely focused on characterizing and understanding the health impacts of climate change, rather than on mitigation and adaptation responses. A rebalanced agenda must prioritize research on underrepresented populations, underresearched impacts, and above all on the response to climate change rather than simply the nature of the problem. This requires embracing knowledge pluralism and place-based solutions to ensure innovations reach the most vulnerable communities.

2. **Develop the architecture for effective evaluation**

   Overcoming the barriers to evaluation of health adaptation interventions requires building new architecture within the academic and broader community. This includes new consensus on a common taxonomy, shared standards for assessing intervention effectiveness and economic valuation, and consistent guidance on how to compare outcomes across contexts.

3. **Accelerate innovation from pilot to scale**

   Establish institutional mechanisms and dedicated financing to systematically identify, test and scale up proven innovations. While ongoing work has produced a diverse range of successful innovations – from high-tech solutions such as medical drones and AI-enabled forecasting to low-tech approaches such as passive cooling or regional supply hubs – many remain localized, have yet to achieve wider adoption.

5.1 Introduction

While there is more than enough evidence to support and guide early and current action, without innovation, research and proper evaluative processes, progress in the field risks stalling. Each preceding section – on equity, health information systems, infrastructure, workforce, governance and financing – has underscored the same lesson: that delivering resilient, low-carbon health systems depends not only on the effective implementation of known solutions but also on the systematic generation, testing and scaling of new ones. The health profession has a strong tradition of innovation and quality improvement in clinical practice and public health, though scaling success is a persistent challenge, with new solutions remaining localized or failing to reach wider adoption.

If the successive literature reviews conducted across the previous sections have demonstrated anything, it is the need to both prioritize research, innovation, and learning environments, and to professionalize monitoring and evaluation processes. The field lacks consensus on agreed health adaptation taxonomy, shared standards for assessing intervention effectiveness, consistent methods for the economic valuation of health and wider endpoints, and limited guidance on how to measure or compare outcomes across diverse contexts (315). As a result, it remains difficult to judge which interventions work, their cost and the economic value they generate, which are scalable, and which should guide future investment. These challenges are common to broader adaptation efforts, with many of the challenges and related opportunities shared with the health sector (Table 7).

Table 7: Common monitoring and evaluation barriers and related opportunities in adaptation interventions (Adaptation Committee, 2023) (316)

Category	Barriers and challenges	Related opportunities
Development of indicators	No common metrics, indicators, or definition of success/effectiveness for adaptation	Review existing indicators from literature or other contexts Prioritize indicators based on significance and data availability Use qualitative and quantitative methods to assess progress
Uncertainty and long time horizons	Climate change impacts and adaptation results are uncertain and take a long time to manifest	Adopt a learning-by-doing approach and adjust over time Institutionalize learning in the monitoring and evaluation (M&E) system, e.g., through the development of a formal learning system
Data availability and reporting	Limited availability of high-quality data related to adaptation Lack of or unclear reporting mechanisms for adaptation information	Develop agreements with national institutions to enable the transfer of data needed for the M&E system Raise awareness of the importance of continuous and standardized data gathering for adaptation Engage a wide range of stakeholders to collect additional information and ensure a comprehensive and inclusive assessment of progress Establish institutions responsible for adaptation monitoring across sectors
Capacity	Lack of technical and human capacity to design, implement, and sustain M&E systems for adaptation	Align M&E systems with related reporting obligations and practices to avoid further strains on capacity Where necessary and feasible, establish new institutional structures, such as dedicated teams, devoted to M&E Seek technical support from relevant organizations Adopt a simplified M&E approach if initially envisioned system is beyond current capacity
Financial resources	Lack of sufficient resources to support design, implementation, and long-term sustainability of an M&E system	Seek financial and technical support from relevant organizations
Transition from development to system application	Difficulty implementing M&E system as planned	Identify key operational details at the time of design to ensure feasibility e.g., for indicators, the data source, data collection method, collector, start date, and cost of data Begin with a simplified M&E approach and increase in sophistication over time

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5.2 Research, monitoring and evaluation

The academic literature focusing on the intersection of health and climate change has developed significantly in both quality and scale since its foundations in the early 1990s. The Lancet Countdown's broad review of the evidence suggests some 57 000 articles have been published on the topic between 1990 and 2024, with 10% of these published in just the last 12 months (4). The vast majority of these (94%) focuses on the impacts of climate change on human health (79%) and health adaptation measures available (15%). Two things are particularly notable here and have been widely reflected in the literature. First, the field has been primarily concerned with describing the current and future states of climate change, rather than exploring and evaluating the interventions and response measures required (296,317,318). Second, vanishingly few studies focus on either the health co-benefits of mitigation or healthcare decarbonization itself. Concerningly, of the articles that specify a geographic location, 76% of them are focused on Very High or High HDI countries, with only 23% covering Medium and Low HDI countries (Fig. 15) (4).

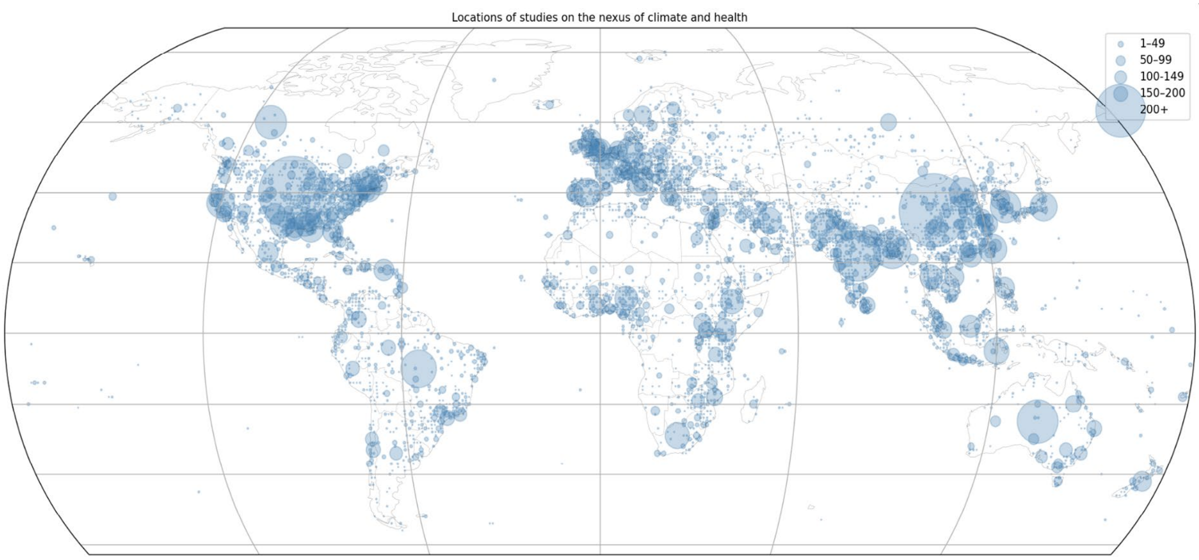

Fig. 15: Geographical distribution of the scientific articles on health and climate change (4).

The evidence reviewed in preparation for this Special Report has revealed a number of gaps and areas for deeper investigation over the coming decade, aligned with the priority areas identified by various assessments conducted by the community (319).

First, as highlighted by the Belém Health Action Plan's first principle, the research and wider health community needs to improve research efforts specifically targeting the nexus of health adaptation and equity. While good work exists, previous sections have already demonstrated the ways in which certain impact pathways (mental health, population displacement) and population groups (people with disabilities, outdoor workers, migrant populations and Indigenous populations) are significantly underrepresented in the research (34,56,320,321).[BHAL 26] Success here requires the collection of disaggregated data and the support of broader research methods that embrace knowledge pluralism rather than shy away from it (322,323). Bridging the gap between research and implementation, a number of countries have adopted local variations of the citizens assembly methodology, enabling cocreation and supporting adoption and resilience.

Second, the integration of global knowledge with local context is key.[BHAL 21] Place-based solutions ensure adaptation actions are tailored to local context and priorities, often improving effectiveness and equity outcomes associated with interventions (324–326). The development of a place-based approach requires an understanding of the context and social drivers of vulnerability, local governance and regulatory frameworks, core behaviour change factors, and a more personalized understanding of adaptive capacity at both the individual and community scale (327–329).

With the exception of a few bright spots in the literature, there is significantly more work to do in quantifying the financial implications of climate change on health systems, and the corresponding costs and financial benefits of adaptation responses (330). More research is needed to understand the combined and longer-term effects of multiple, concurrent climate events and cascading risks, to identify new emerging threats such as vector-borne diseases (331–333). This includes accurately costing the impact of extreme weather event-related disruption to routine healthcare provision. Alongside published peer-reviewed research, post-event debriefs and lessons learned provide a rich source

BHAL 26: Integrating climate and mental health care

BHAL 21: Uniting sectors against climate-driven malaria

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of information that should be utilized to identify knowledge and operational gaps, and opportunities to improve resilience.

Finally, and perhaps most importantly, evidence remains relatively limited on the effectiveness and scalability of adaptation interventions in the health sector, and the economic benefits and costs of these actions (315). The majority of studies are either describing the impacts of climate change, modelling studies which assess the health effects of theoretical interventions, descriptive case studies or global frameworks (334). The Lancet Pathfinder Commission's thorough review of the parallel mitigation and health co-benefits evidence demonstrated the lack of high-quality and independent evaluative studies (335). This is in part an artefact of the way the field has developed. Early work has been focused on demonstrating that climate change is an important issue in need of attention from mainstream actors such as health systems and health ministries. Having achieved that, and with a wide variety of interventions now underway across the world, the literature has yet to fully adjust. Recent work to address this issue includes the new "SCALE-up framework", which suggests six core considerations to assess the effectiveness of health adaptation interventions, with initial iterations calibrated for heat, floods, drought and malaria (Fig. 16) (334). Many adaptation actions are complex interventions that embody systems approaches including multiple interacting components, comprising technologies, behaviour change interventions, health systems strategies and governance mechanisms. Evaluative research should therefore aim to follow good practice for the design and evaluation of complex interventions including health, environmental, economic and social outcomes as appropriate (336).

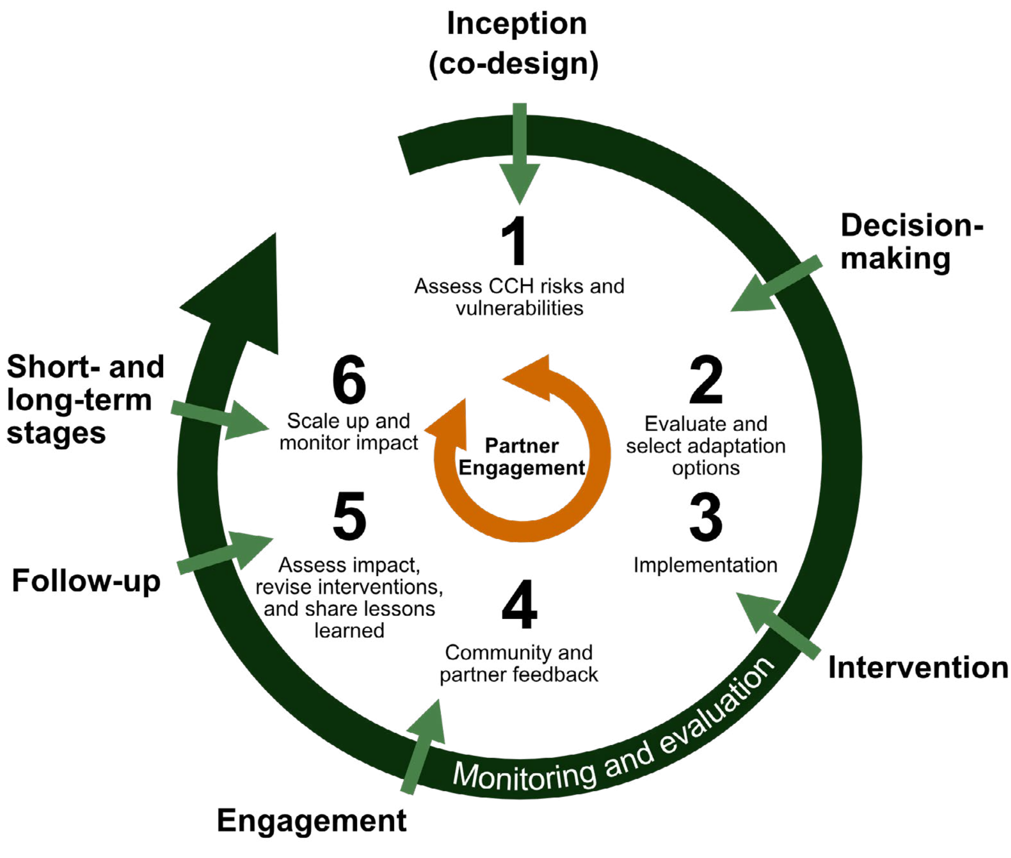
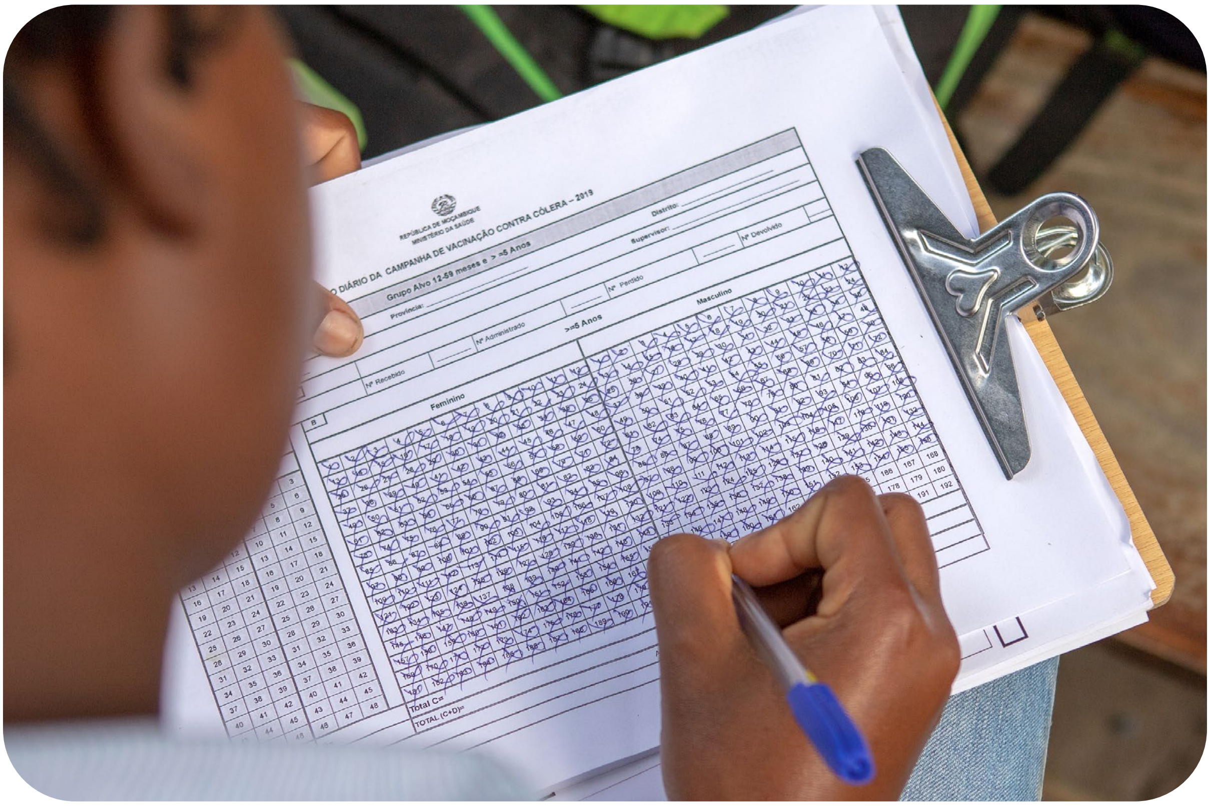


Fig. 16: Guiding concept to inform the development of a climate change-health-adaptation assessment framework to evaluate effectiveness (334).

While iterative monitoring and evaluation processes are built into many of the published resilience frameworks, the majority of the evaluation literature remains focused on individual projects, funding cycles or communities (337). Comparatively few studies assess implementation progress quantitatively at the national level (338,339). A comprehensive review of the degree of evaluation undertaken for National Adaptation Plans suggests that majority (over 60% worldwide) are not being formally tracked or evaluated. While this also suggests that 40% have conducted some form of evaluation process, only three of these are from Least Developed Countries (110).

One excellent exception to this is Panama's Adaptation Monitoring and Evaluation System, established by Executive Decree in 2021 and developed in parallel with the country's Nationally Determined Contributions. Part of the multistakeholder Initiative for Climate Action Transparency, the MEL system includes 37 indicators (21 for adaptation and 16 for Loss and Damage) to strengthen institutional and interinstitutional capacities (340).

Lessons learned thus far include: 1) M&E systems for adaptation require capacity-building and awareness-raising of the importance of continuous and standardized data gathering, as well as enhanced data storage structures and data quality standards; 2) sufficient human resources with appropriate skills and expertise are an essential requirement for the follow-up and monitoring of indicators; 3) sustained institutional support is necessary to drive data collection; and 4) M&E of adaptation is a long-term effort, requiring constant resourcing and political focus, and ongoing strengthening (340).



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5.3 Emerging innovations

As technology, the climate, and the field evolve, new innovations are increasingly finding their way into practice. Throughout this report, a wide range of novel approaches have been explored, grouped into four broad (and often overlapping) categories of innovation: technological; data and analytical services; infrastructure and the physical environment; and service design and systems.

5.3.1 Technological innovation

As one of the most innovative sectors in society, health and healthcare is well-placed to develop new technologies to better respond to a changing climate, developing new tools that directly protect people, sustain essential services, and preserve medicines under climate stress. Examples of such technological innovation include:

- **Solar direct-drive vaccine refrigerators** providing reliable cold chain capacity independent of the grid. Malawi's national rollout protected vaccine stocks across the country during Cyclones Ana and Freddy (190).

- **Heat-stable pharmaceutical formulations** of antimalarials and antiretrovirals supported by UNITAID reduce dependence on energy-intensive refrigeration and improve treatment efficacy in high-temperature environments.

- **3D printing of essential medical equipment** during periods of climate stress and supply chain disruption often complements preexisting reprocessing and resterilization techniques (341).

- **Medical drone delivery networks** have been shown to be effective in a number of settings, from Timor-Leste to the National Health Service in the United Kingdom, delivering blood, vaccines and medicines while reducing costs, delays and emissions (342,343).

- **Wearable heat resilience technologies** including heat stress detection devices that alert outdoor workers and patients to early signs of heat exhaustion, and active, passive and hybrid cooling garments that modify individual microclimates, supporting healthcare staff and patients (344–347).

5.3.2 Innovation in data and analytical services

Stronger data collection systems, the advent of machine learning and artificial intelligence, and new attribution methods enable greater preparedness and earlier warning, more efficient responses, and improved coordination across the health sector.

- **Moving from global to local**, the next phase of the Lancet Countdown's work is focused on building regional capacity and locally-relevant indicators and datasets to provide decision support for health systems across the world (4).

- **The integration of health and climate data into electronic medical records and DHIS2** (District Health Information Software 2) is beginning to empower the 80 ministries of health currently utilizing the service.[BHAL 13] By incorporating local environmental data into DHIS2, Malawi's Health Ministry, Agriculture Ministry, and meteorological services have created an early warning system for flood, drought and food insecurity (348–352).

- **AI-enabled energy management systems** optimize renewable energy use and stabilize microgrids within hospitals, enhancing both energy efficiency and resilience (353).

- **Enhanced hazard forecasting** is being combined with machine learning techniques to improve flood and wildfire predictions, enabling better predictions of the health consequences of damage to sanitation systems and blaze spread (354,355).[BHAL 4 & 30]

BHAL 13: Integrating climate data into health systems

BHAL 4: Integrating forecasts to fight disease

BHAL 30: Using AI to predict dengue outbreaks in India

5.3.3 Infrastructure, supply chains, and the physical environment

From passive cooling and energy-efficient design to climate-resilient siting and low-carbon materials, many of the most effective innovations combine engineering advances with traditional design principles to ensure resilience in both high- and low-resource settings.

- **Cool roof technologies** lower peak ambient and surface temperatures by 2.3 °C and 6.1 °C respectively with low-cost adaptations such as reflective roof paint adopted in Ahmedabad (356,357).

- **Passive and nature-based cooling systems** including green facades, natural ventilation, and phase change materials reduce reliance on mechanical air conditioning, lower energy demand and improve heat resilience (174).

- **Prepositioning and regional supply hubs** decentralize storage of essential medicines and medical devices, and have been rolled out to support Pakistan's national monsoon contingency plan and United Nations Population Fund (UNFPA)'s network of response hubs across the Asia-Pacific region (192,193).
- **Climate-resilient building codes** requiring integrated risk modelling and innovative climate-ready design and materials have yielded cost–benefit ratios of 11:1 when compared to conventional construction methods and design (176).

5.3.4 Health service design and systems innovation

- **Remote care and telemedicine** offer new ways to improve health service efficiency and increase access, particularly in rural and remote areas and at times of transport infrastructure disruption (358).
- **Participatory, patient, and community-led design** ensures public health and clinical services are culturally and locally appropriate, as seen in Australia's Person-Centred Emergency Preparedness protocol.[BHAL 45]
- **Climate-resilient primary care** systems are the backbone of any adaptation strategy, made stronger when integrated with broader cross-sector community resilience measures and supported by onsite and off-grid renewable power (359).
- **Blended and results-based finance models** provide an opportunity to dramatically increase available resource. Results-based financing links funding to measurable outcomes (such as service continuity or resilience standards), while an example of blended finance might include combining national-level public funds with MDB-provided concessional finance and private sector investment (330).

BHAL 45: People-centred emergency preparedness

Taken together, these innovations illustrate the need for a balanced approach that explores high- and low-tech solutions while remaining grounded in the local context. Sustained progress will depend on countries' institutionalization of innovation within health planning and financing cycles, strengthened evaluation and knowledge exchange, and continued funding from public and philanthropic agencies.

Ultimately, delivering on the promise of the Belém Health Action Plan will require sustained commitment to research and innovation as a core function across the entire health sector. Institutional mechanisms that support research, innovation, and continuous learning within health adaptation programmes and health ministries will help ensure that new approaches are rigorously evaluated and scaled equitably.

Limits, synergies and a systems approach

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Recommendations

1. **Urgent mitigation and the Belém Health Action Plan are inextricably linked**

   Meeting the commitments under the Paris Agreement through urgent mitigation efforts is the single most important action to delivering on the promise of the Belém Health Action Plan. This requires deep, near-term emissions reductions in energy, transport, land-use and health sectors to prevent escalating health risks, contain adaptation costs, and protect health systems.

2. **Prioritize integrated health adaptation and mitigation planning and a systems approach**

   Interventions to address climate change, and their impacts on health, involve complex systems. National Adaptation Plans and Nationally Determined Contributions should systematically identify and prioritize actions that strengthen both health resilience and reduce emissions, explicitly realizing the cost–savings and public health benefits of these synergies. Joint planning and monitoring mechanisms that systematically assess health outcomes in climate policies have been shown to support a systems approach across government.

3. **Harness the financial returns of mitigation to fund health adaptation**

   Many health system decarbonization efforts are cost-effective, generating operational savings that can be directly reinvested into health system resilience and adaptation measures. Health systems should systematically identify and capture these financial returns from mitigation actions to create a self-sustaining funding mechanism for adaptation priorities.

6.1 Introduction

Each of the previous sections in this Special Report has focused on translating the evidence on health adaptation into action. It is critical to acknowledge that there are profound limits to adaptation that cannot be surmounted, no matter the financial resource or political commitment. As stated in the introduction, the literature reiterates repeatedly that one of the most important adaptation questions is, "what world are we adapting to?" The nature of an intervention designed for a 1.5 °C world is fundamentally different to one designed for a 2 °C, 3 °C, or even 4 °C world. To this end, efforts to limit the extent of heating are an essential part of any adaptation strategy, often also bringing important health co-benefits which in turn enhance population resilience.

Understanding and managing the interactions of these concepts is the core focus of this section, which will examine the limits and constraints to health adaptation, the synergies between adaptation and mitigation within a formal health system, and the health co-benefits of mitigation.

6.2 The physical, financial and technological limits to adaptation

Adaptation, while essential, cannot fully protect health systems or populations from the escalating impacts of climate change – its capacity is bounded. Fig. 17 provides an illustrative range of development pathways, with greater adaptation challenges occurring under higher emission scenarios, as underscored by the IPCC's emphasis on both hard and soft limits (360).

Hard limits involve thresholds beyond which no adaptation is possible. These may be due to physical or biological constraints (e.g., human physiological limits, areas becoming uninhabitable due to heat, sea level inundation, loss of essential ecosystem services). Soft limits occur when no further adaptation options are available, though they may become feasible in the future. These barriers are often determined by financial, governance, institutional and policy constraints (360).

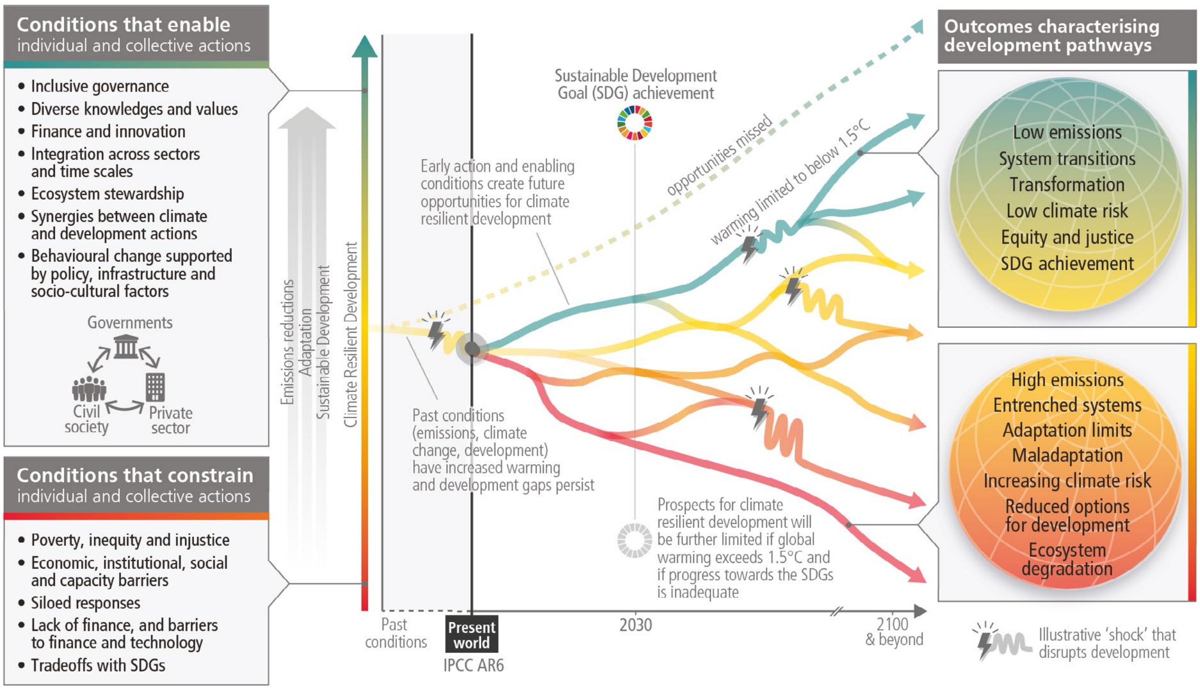

Fig. 17: A narrowing window of opportunity (34).

6.2.1 Physical and biological limits

With increasing warming, adaptation options become more constrained and less effective (34). Mitigation action is thus essential to limit future warming. Examples of physical and biological limits include:

- **Limits of physiological tolerance**: humans have hard limits for tolerance of heat and humidity (361). Vulnerable populations can tolerate less (362). As warming increases, such limits may be exceeded more frequently for a greater proportion of the population, meaning that at high levels of heating, some currently inhabited places become uninhabitable (361,363). For example, moving from a 2 °C to 4 °C scenario is projected to increase the number of people experiencing more than one month of "intolerable" heat and humidity per year by more than 1 billion (361,364).

- **Daily temperature limits**: epidemiological studies have established sound evidence that the risk of mortality gradually increases with daily mean temperatures above a relatively low threshold in the present climate, and the proportion of deaths attributable to high temperatures is around 0.4% of total deaths (363). In 2100, there could be 90 000 European deaths from extreme heat per year under 3 °C degrees of global heating (three times that of 1.5 °C degrees of warming) (365). While these effects can be reduced by adaptation to some extent, when approaching the hard limits of liveability, further adaptation may no longer be possible (361,366).

- **Geographic limits**: in a range of warming scenarios, currently densely populated areas are likely to become permanently flooded or completely lacking fresh water.

Here, no amount of investment in health can maintain the habitability of such places. Hard limits to adaptation for some coastal communities begin at 1.5 °C, while hard limits for water management begin at 3 °C (367).

6.2.2 Financial constraints

The health system's ability to adapt depends heavily on financing – both to build capacity, infrastructure, workforce capacity and a range of other interventions. With global healthcare budgets already strained across all income settings, there is rarely additional funding available.

- **Limited budgets:** a scoping review of the response of health systems to climate change adaptation highlighted financial constraints as the single greatest barrier (73). The underfunding of health services leaves too few resources to effectively address multiple competing demands (59). Scaling up adaptation (such as surveillance and resilient infrastructure) demands sustained financing that many governments lack. As described in the financing section above, there is an upward trend in health adaptation funding. Unfortunately, this upward trend is currently, perhaps invariably, being outpaced by the pace of the impacts it is designed to prevent.

- **Budgetary trade-offs:** while investment in strengthening general health systems increases resilience, targeted investment is also required to improve the response to climate-sensitive exposures (20). Funds allocated to adaptation may divert resources from basic healthcare services, creating difficult choices between immediate needs and long-term resilience (20).

- **Insurance and financing challenges:** limited access to affordable insurance for climate-related damages leaves health systems financially exposed (368). Climate change can reduce the insurability of some risks, and widespread catastrophic losses could lead insurers to pull out of certain markets, creating cases of un-insurability.

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6.2.3 Technological constraints

Technological solutions are subject to certain constraints:

- **Physical infrastructure constraints:** ultimately, no part of a health system's infrastructure can be entirely climate-proof. Even the most advanced engineering standards have structural limits, and over time, these will be exceeded by the scale or frequency of extreme events. Floods can submerge power systems, storms can tear roofs from hospitals, and prolonged heat can degrade materials faster than designed tolerances allow (158).

- **Supply chain and resource constraints:** even with high-quality plans, physical availability of materials (e.g., cooling equipment, building materials, power, clean water) may be constrained. Extreme weather can disrupt supply chains; some materials degrade under high heat and humidity; and water scarcity limits health facility hygiene (369).

- **Energy infrastructure:** Adaptation often depends on a reliable power supply (for cooling, ventilation, water pumping, surveillance, digital systems etc.), which creates interdependency with wider national energy systems. In many regions, energy grids are unreliable, and expanding or making them resilient is costly. Moreover, if the energy is fossil fuel-derived, adaptation via increased energy consumption may contradict mitigation goals (170).

Given these hard and soft limits to adaptation, the urgency of fossil fuel phaseout and reductions in global greenhouse gas (GHG) emissions is clear. Adaptation becomes more challenging the greater the level of warming, with mitigation helping to limit residual risk and lower the chances of crossing a hard limit. Mitigation also slows the pace of change, creating more time for adaptation, research and capacity building. Many health systems have had great success taking the savings from their decarbonization efforts and reinvesting them in health system resilience. As the broader COP30 Presidency Action Agenda makes clear, no adaptation strategy, including the Belém Health Action Plan, can be achieve its goals without the other half of the response to climate change (15).

6.3 Synergies between health adaptation and mitigation

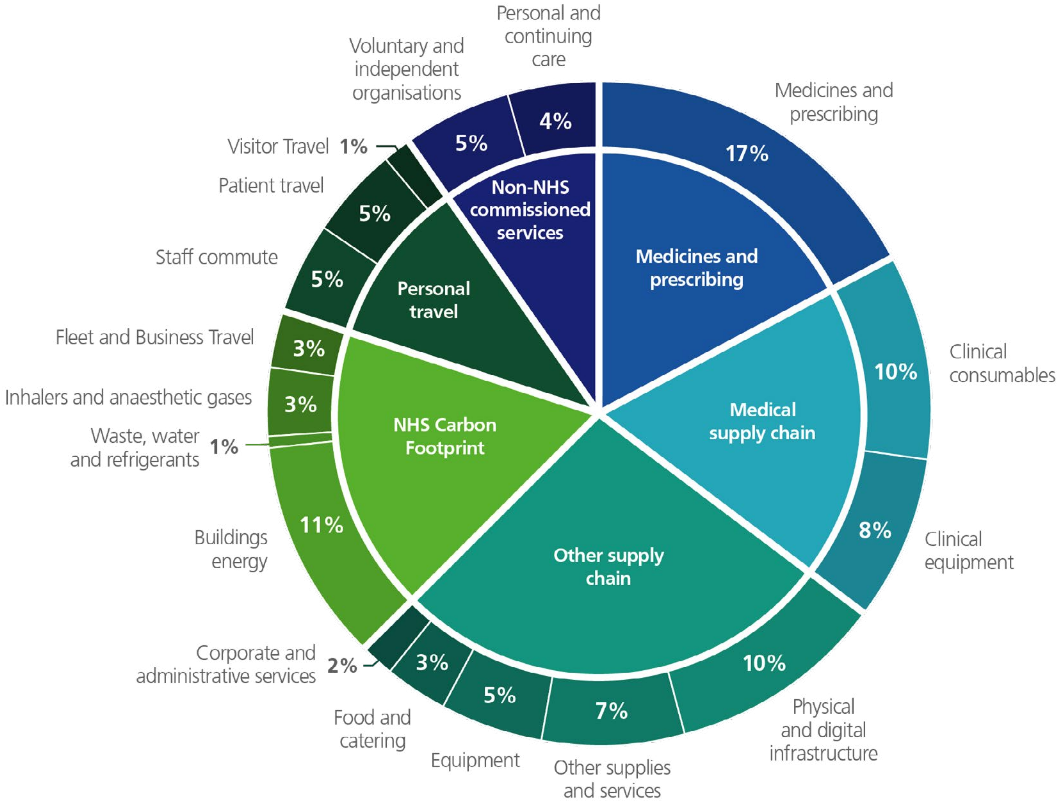
Mitigation and adaptation are often treated as separate aspects of climate policy, though the Paris Agreement makes clear: an integrated approach is the only approach that will be successful (39). In many cases, health adaptation benefits directly from mitigation actions, and vice versa.

Key mitigation actions that support health adaptation

Many mitigation strategies simultaneously enable healthcare facilities to adapt to climate change, or are able to offer cost savings that can be reinvested in adaptation. For example, investment in onsite renewable energy generation reduces energy emissions, increasing resilience against weather-related power cuts. The mitigation impact can be significant when strategies are combined, such as a 30% reduction in energy consumption for Woodlands Hospital through the utilization of passive cooling, solar photovoltaic panels, green infrastructure and rainwater harvesting, all whilst improving climate adaptation (370). Similarly, nature-based solutions can integrate adaptation and mitigation if well-designed with the full involvement of Indigenous groups and local communities (335). For example, tree-based interventions including agroforestry can benefit both human health and the environment (371).[BHAL 23] Health systems, including public health professionals, have an important role in supporting multisectoral action for health and for the climate (372,373).

Fig. 19 summarizes the emissions of a health system in a high-income setting (the NHS in England) 8and a middle-income setting (the Philippines) (374,375). The emissions hotspots highlighted in each come with a host of associated decarbonization interventions, many of which have direct adaptation co-benefits, as exemplified in Table 8.

BHAL 23: Turning urban heat into policy action



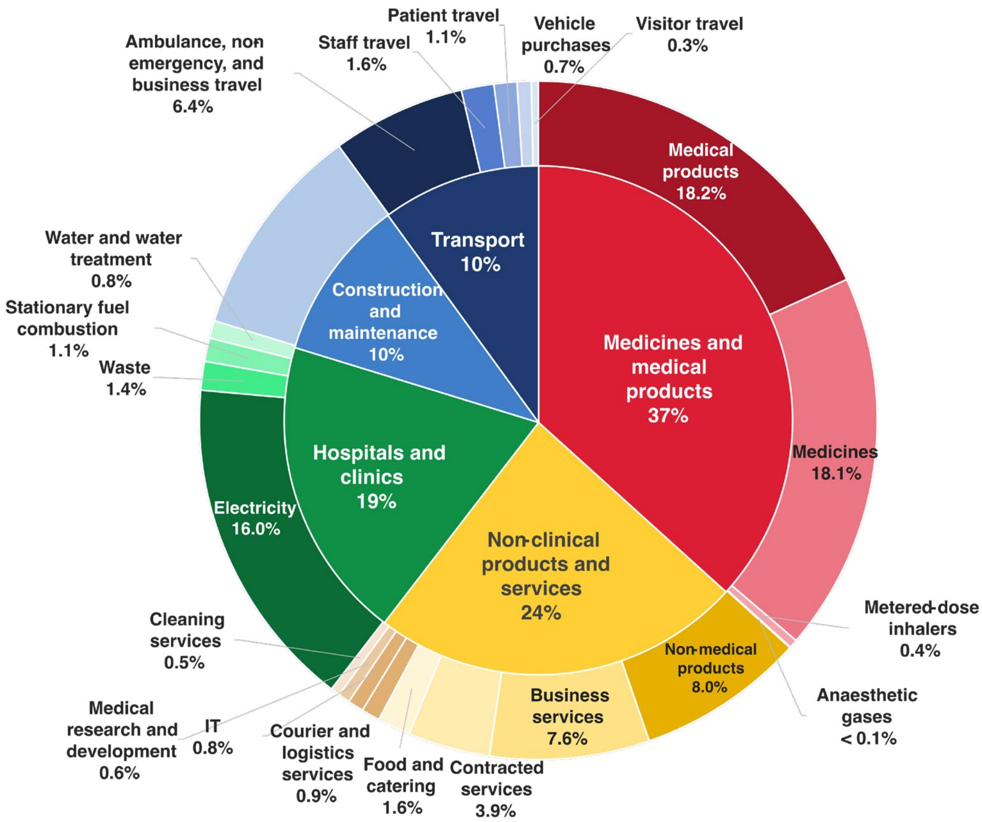


Fig. 18: A comparison of health system emissions in England (top) and the Philippines (bottom) (374,375).

Table 8: Synergies of mitigation and adaptation action in health systems

Type of synergy	Examples
Creation of green spaces associated with health services infrastructure, giving both mitigation and adaptation benefits Green spaces (and other forms of green infrastructure such as green roofs and walls) can play an important role in improving air quality. Trees and vegetation can absorb carbon dioxide as well as harmful pollutants, such as particulate matter and nitrogen dioxide, resulting in healthier environments that can benefit patients, staff and surrounding communities.	The Royal Devon University Healthcare (RDUH) NHS Foundation Trust transformed 26 000 m^2 of mown lawn into perennial urban meadows. The project saves an estimated 22.8 tonnes CO_2e annually, while tripling plant and insect diversity, and boosting wildlife populations. Meadows also increase surface reflectance, mitigating urban heat and maintaining cooler local microclimates. Beyond climate impacts, feedback from staff and visitors was positive. The RDUH case illustrates the broader potential of NHS-owned land (around 6,500 hectares nationally) to be leveraged for climate action (376).
Mitigation actions generating cost savings, allowing reinvestment in adaptation action Many mitigation strategies yield cost savings or reduce operational costs in health systems. For example, improving building energy efficiency, transitioning to cleaner renewable energy, or high-value care streamlining.	Gundersen Health System in the US launched a clean energy programme in 2008 aimed at reducing pollution and operating costs. Through a combination of energy conservation, wind generation, landfill biogas, and other renewable energy initiatives, the health system achieved over a 90% reduction in GHG emissions from 2008 to 2016. These actions resulted in substantial financial savings, with energy spending falling below 2008 levels (377).
Reducing exposure to indoor heat via adaptation action, delivering mitigation co-benefits For example, adaptation of health system buildings with passive cooling strategies reduces air conditioning need and the associated waste heat exhausted to the local environment and GHG emissions.	Modelling work carried out to identify scalable retrofit interventions that reduce overheating for care homes demonstrated that measures such as external shading and glazing films are often cost-effective, offering substantial reductions in indoor temperatures and heat mortality, and reduced cooling demand when combined with air conditioning (378,379).
Enhancing resilience and reducing vulnerability through low-carbon infrastructure Mitigation may strengthen systems in ways that improve adaptive capacity. For example, investing in cleaner energy, microgrids, and energy efficiency in health facilities reduces the risk of power outages during extreme weather and reduces GHG emissions.	In Kyrgyzstan, solar water heaters and photovoltaic systems in hospitals provide a resilient supply of energy, which both adapts to unreliable supply and mitigates GHG emissions (380). Across sub-Saharan Africa, decentralized solar microgrids provide a clean and reliable solution that strengthens resilience (381–383). In Rwanda, solar systems in five clinics have powered diagnostics, refrigeration and communication for nearly 400 000 people (384,385).
Joint planning and policy integration Cross-sector coordination enhances recognition of both adaptation and mitigation within health policy and in national climate and health strategies. BHAL 65	The deployment of green and blue urban infrastructure in European cities helps both mitigation (carbon sequestration, cooler cities needing less cooling energy) and adaptation (reducing heat, improving air quality, and mental health).

BHAL 65: Integrating health into Kenya's climate agenda

6.4 The health co-benefits of mitigation in other sectors

While the majority of this Special Report has addressed the health sector, under the direct control of a ministry of health, mitigation actions across the rest of the economy deliver profound co-benefits for health and health systems (See Box 6) (335,386). This section gives examples of mitigation actions in other sectors and the related co-benefits for health and the broader Sustainable Development Goals.[BHAL 69] In some cases, the mitigation actions also provide direct co-benefits for health system adaptation (e.g., urban greening both sequesters carbon and reduces local temperatures, easing the related heat-related burden on health systems) (387).

BHAL 69: A whole-of-society approach to climate resilience

Box 6

Harnessing the health benefits of climate action

Reviewing evidence centred on the health benefits of mitigation from across the world, the Lancet Pathfinder Commission identified three main pathways that contained the most significant gains for public health (335). These included reduced air pollution from phasing out fossil fuels and transitioning to clean energy; shifting to healthier, more sustainable diets; and increased physical activity from active travel alongside public transport. While the scale of the opportunity is substantial, amounting to many millions of premature deaths prevented worldwide each year, the nature of the evidence mirrors that identified in this report. The majority of the studies come from modelling studies and guidance showing potential benefits, with comparatively few evaluations of implemented actions.

The mitigation climate and health evidence bank showcases these solutions (388). It highlights actions across different sectors, scales and regions, such as transitioning to renewables in the US, promoting active travel in Buenos Aires and cities in New Zealand, improving energy efficiency of homes in Victoria in Australia, providing sustainable school meals in Sweden and protecting forests while supporting local communities in Tanzania and Indonesia (389–394).

Further evidence from the Pathfinder Initiative shows the potential for nature-based solutions such as tree-based interventions (actions where trees are a central feature to address environmental challenges) to bring significant health and livelihood benefits and contribute to both climate mitigation and adaptation goals (371). Integrating climate mitigation and adaptation strategies, as well as carefully considering community needs in the design and implementation of climate solutions is vital to maximize health benefits, minimize unintended negative impacts and accelerate a just transition to a net zero future.

6.4.1 Energy sector

- **Phasing out fossil fuels and transitioning to renewable energy:** replacing fossil fuel power plants with cleaner, renewable sources reduces ambient air pollution and the associated health impacts (395). Fossil fuels were responsible for 61% (5.1 million) of deaths related to fine particulate matter ($PM_{2.5}$) and ozone worldwide (23).

6.4.2 Transport sector

- **Active and public transport:** policies promoting walking, cycling, and public transit reduce vehicle emissions, improve air quality, promote physical activity, reduce obesity, and improve cardiovascular and mental health (396,397).[BHAL 36]
- **Electrification of transport:** switching from internal combustion engine vehicles to electric vehicles (especially when powered by renewables) reduces both GHG emissions as well as air and noise pollution (398).
- **Urban design and infrastructure:** designing cities to reduce travel distances, improve public transit and provide safe walking and cycling infrastructure can reduce GHG emissions and exposure to air pollution (360,399).
- **Potential asthma reduction impact:** land transport is responsible for 44% of the approximately 3.5 million incident cases of asthma in children and adolescents worldwide attributed to ambient NO_2 levels (400).

BHAL 36: Cycling for health and sustainability in Argentina

6.4.3 Food, agriculture and land use sectors

- **Shifts to more sustainable food systems:** reducing meat consumption, improving farming practices and food distribution, and reducing food waste mitigates GHGs and also addresses dietary health risks. Shifting away from animal-sourced food reduces GHG emissions and could save an enormous US$ 7.3 trillion from production-related health and ecosystem degradation burdens (401).
- **Land use, reforestation, and forest protection:** interventions help carbon sequestration, while also providing ecosystem services: water regulation, flood protection, erosion control, vector regulation, mental health benefits and biodiversity preservation. In Brazil, reducing deforestation by 1 million hectares was estimated to reduce malaria incidence by 2.7 cases per 1000 people and dengue fever by 0.1 cases per 1000 people in rural areas. Afforestation and forest conservation efforts could decrease malaria cases by up to 50%, equivalent to 14 avoided cases per 1000 people (402).

6.4.4 Housing, urban planning, buildings

- **Energy-efficient buildings:** better insulation and improved airtightness, when accompanied with adequate ventilation levels and appropriate passive design measures, reduces energy demand, increases resilience to heat and cold, and reduces indoor exposure to air pollution (403,404). One pilot intervention in Dublin (2016–2020) provided improvements to the energy efficiency of households with occupants aged 55 years and over with chronic respiratory conditions. Postintervention, general practitioner consultations fell by 25.6% and emergency room visits for respiratory conditions fell by over 50% over six months. The participants reported improvements in physical health, general health and social well-being, and statistically significant reductions in monthly drug prescriptions in the following year (405).

- **Household energy improvements:** switching from biomass or polluting solid fuels to cleaner heating systems and cookstoves reduces indoor and ambient indoor air pollution, with the health co-benefits especially large in LMICs (25,405).

- **Urban green and blue spaces:** trees, parks, wetland buffers and green space all reduce ambient air temperatures, thus reducing the burden on health services, sequestering carbon, reducing flood risk, improving air quality, mental health and social well-being (406,407). Importantly, these benefits depend on planting the right trees in the right places to avoid unintended adverse consequences including heat trapping and allergies (408).

The Belém Health Action Plan rightly focuses on health sector adaptation to climate change. The broader COP Presidency Action Agenda, the Paris Agreement, and the scientific literature are in full alignment: adaptation without mitigation will ultimately be unsuccessful. It will meet insurmountable costs, a less healthy baseline population, and hard technological and physiological limits. A balanced approach, which seeks to identify synergies both within and beyond the health sector is clearly essential.

Conclusion

> **Health is where the climate crisis becomes real – and where the solutions begin.**

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Across every section of this Special Report, one message is heard again and again: the time for incremental progress has passed. Climate change is already eroding the foundations of health and well-being, widening inequities and testing the limits of our health systems. Yet the same evidence shows that decisive, coordinated action can deliver extraordinary returns, measured in stronger, fairer and more sustainable health systems and societies.

This report has translated the growing body of science into a framework for action. Success depends on embedding health equity at the heart of adaptation planning. It requires empowering a skilled and prepared workforce; hardening our physical infrastructure against inevitable shocks; harnessing data through evidence-based and interoperable information systems; and securing predictable, accessible finance. These pillars, in turn, depend on coordinated and accountable governance that bridges sectors, engages communities, and translates policy into practice. Together, these elements form the operational backbone of the Belém Health Action Plan.

At the same time, the science is clear: without urgent and sustained global emissions reductions and fossil fuel phaseout, the limits to adaptation will quickly overwhelm even the most strident of resilience measures. The path from evidence to action now depends on political commitment. This document is full of implementation-ready, no-regret interventions, and the Belém Health Action Library provides real-world examples that demonstrate that progress is possible.

The cost of inaction will be counted in escalating disease burdens, economic losses and irreversible harm; the benefits of action will be felt across generations. Health is where the climate crisis becomes real – and where the solutions begin.

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