

Heat and Health Adaptation at Scale:

Evidence on Gaps, Innovations, and
Investment Opportunities from India



A Report by
India Health Fund





Heat and Health Adaptation at Scale:

Evidence on Gaps, Innovations, and Investment Opportunities from India

A Report by India Health Fund

Authors

Dr. Saurabh Mamtani

Ms. Gargi Deshmukh

Suggested Citation:

Mamtani Saurabh, Deshmukh Gargi. 2026. Heat and Health Adaptation at Scale: Evidence on Gaps, Innovations and Investment Opportunities from India. Mumbai: India Health Fund



**Dr. Soumya
Swaminathan**

Chairperson - M S
Swaminathan Research
Foundation (MSSRF)

Foreword

Extreme heat is no longer a distant consequence of climate change. It is at present an intensifying threat to human health, livelihoods, productivity and the resilience of our communities and health systems. Yet, heat should not be viewed only through the lens of crisis. It is also a test of how effectively we can bring together science, public policy, technology, finance and implementation to build systems that are better prepared for a warmer future.

India has made significant progress in translating the growing recognition of extreme heat into institutional action. Over the past decade, the country has built a progressively stronger architecture for heat preparedness - from the National Disaster Management Authority's Heat Wave Guidelines and the development of Heat Action Plans to increasingly granular forecasting and impact-based warnings from the India Meteorological Department. These are important achievements. They signal that India has moved beyond recognizing heat simply as a meteorological phenomenon or seasonal hazard, and towards treating it as a risk that demands coordinated action across disaster management, public health and local governance. The next frontier, however, is more demanding: how do we convert increasingly sophisticated forecasts, surveillance systems and plans into sustained, measurable and equitable protection for the people and communities who are most at risk?

This report makes an important contribution to that transition.

A key strength of the report is its treatment of heat-health risk as a multidimensional phenomenon. Heat exposure does not produce uniform outcomes. Health impacts are shaped by the interaction of hazard, exposure, physiological and social sensitivity, and adaptive capacity. This has profound implications for public health planning. The same temperature can produce very different consequences depending on a person's age, occupation, comorbidities, pregnancy status, housing conditions, access to water and cooling, and proximity to health services. A heat-health strategy, therefore, cannot be reduced to a temperature threshold or a warning color. It must be capable of identifying who is at risk, where they are, why they are vulnerable, and what action should be taken.

The opportunity before India is significant. We now have a growing ecosystem of science, policy, technology, civil society, and finance. The imperative is to connect these capabilities - to translate climate intelligence into timely health action, strengthen heat-ready health systems, and ensure protection reaches those most at risk. This calls for a shift from fragmented preparedness to integrated heat-health adaptation, linking prediction, prevention, service delivery, and monitoring. Innovation must be matched by financing and clear pathways to evidence, adoption, and scale. The goal is not more pilots, but solutions that are proven, affordable and embedded in public systems - delivering measurable, equitable protection in a hotter future.

This agenda requires action from the entire ecosystem.

This report is a timely invitation to do precisely that, and I congratulate India Health Fund for developing this vital and timely report on Heat and Health Adaptation. Its recommendations should be seen not as the conclusion of a conversation, but as a starting point for a more coordinated national effort - one that brings together evidence, innovation, policy and capital around a common objective: to ensure that a hotter future does not become an avoidable health catastrophe, but an opportunity to build healthier, more resilient and more equitable societies.

Table Of Contents

Abbreviations	06
Glossary	09
Acknowledgements	11
About India Health Fund	12
Executive Summary	13

CHAPTER I

India is Getting Hotter: Numbers Prove it	16
---	----

CHAPTER II

Heat and Health	22
2.1 Heat and the Human Body: The Clinical Continuum	22
2.2 Risk Framework for Heat and Health	24
2.3 Sensitivity	24
2.3.1 Renal and Cardiovascular Pathways	25
2.3.2 Pregnancy and Heat	27
2.3.3 Older Adults	27
2.3.4 Occupational Exposure	27
2.4 Adaptive Capacity: Knowledge, Geography and Health System Access	29
2.5 Heat and Environment	29
2.6 Evidence Gaps and the Research Agenda	30

CHAPTER III

Heat Action Plans and Adaptation Efforts	32
--	----

CHAPTER IV

Current Heat Adaptation Ecosystem and the Case for an Integrated Heat-Health Adaptation Approach	36
4.1 Mapping India's Heat Adaptation Ecosystem	
4.1.1 Policy and Governance	36
4.1.2 Research & Evidence	36
4.1.3 Civil Society Organisations (CSOs)	37
4.1.4 Technology and Innovation	40
4.1.5 Financing and Insurance	40



4.2	What is needed from the Ecosystem	41
4.3	What Does an Integrated Heat Adaptation Solution Look Like?	42

CHAPTER V

Heat-Health Adaptation Challenges and Innovation Exemplars		46
5.1	Cooling Solutions: Closing the gap between exposure and protection	46
5.1.1	Innovative Cooling Solution Exemplar: Eztia: Scaling Passive Cooling for resilience to Extreme Heat	47
5.2	Digital Intelligence: Closing the Data Gap in Heat Risk and Response.	49
5.2.1	Innovative Solution Exemplar: Climate and Health Vulnerability Index: Closing the Climate-Health gap by turning data into last mile action.	50
5.2.2	Innovative Solution Exemplar: Climateverse: Advancing Data Literacy for Climate Action	52
5.3	Health System Strengthening: Building a Heat-Ready Care Delivery System	55
5.3.1	Innovative Solution Exemplar: CivicDataLab: Building a Climate & Health Data Collaborative for Heat Resilience.	56
5.4	Behavioural Solutions: Translating Awareness into Action	58
5.4.1	Innovation Exemplar: Centring People in Heat-Health Adaptation: The Work of Prayas (Pune)	59
5.5	Lack of Evidence: The Structural Gap that Cuts across Everything	61
5.5.1	Innovation Exemplar: Building the Evidence Base for Heat-Health Adaptation: The Work of MS Swaminathan Research Foundation (MSSRF)	62

CHAPTER VI

Financing Heat-Health Adaptation in India: From Fragmentation to a Unified Innovation Platform		66
6.1	Why Financing Heat Adaptation is Different	66
6.2	Financing Architecture for Heat-Health Adaptation	66
6.2.1	Public Finance	66
6.2.2	The private sector	67
6.3	The Case for Expanding the Tent: Partners with Adjacent Mandates	67
6.4	How Innovative Solutions Are Financed	70
6.5	Towards an Integrated Financing Architecture	71

CHAPTER VII

Call to Action		74
References		76



Abbreviation

Abbreviation	Full Form
ADB	Asian Development Bank
AKI	Acute Kidney Injury
AMR	Antimicrobial Resistance
ANC	Antenatal Care
ASHA	Accredited Social Health Activist
AVPN	Asian Venture Philanthropy Network
B2B	Business-to-Business
B2G	Business-to-Government
CDL	Civic Data Lab
CEEW	Council on Energy, Environment and Water
CHC	Community Health Centre
CHIP	Community Health Integrated Platform
CHVI	Climate and Health Vulnerability Index
CPR	Centre for Policy Research
CSO	Civil Society Organisation
CSR	Corporate Social Responsibility
CSTEP	Centre for Study of Science, Technology and Policy
DALY	Disability-Adjusted Life Year
ERA5	ECMWF Reanalysis v5
ESA	European Space Agency
EWS	Early Warning System
HAP	Heat Action Plan
HMIS	Health Management Information System
HRI	Heat-Related Illness

Abbreviation

Abbreviation	Full Form
HUDCO	Housing and Urban Development Corporation
HVAC	Heating, Ventilation and Air Conditioning
ICAP	India Cooling Action Plan
ICMR	Indian Council of Medical Research
IEC	Information, Education and Communication
IHF	India Health Fund
IIM	Indian Institute of Management
IIPHG	Indian Institute of Public Health Gandhinagar
IITM	Indian Institute of Tropical Meteorology
IMD	India Meteorological Department
IN-SPACE	Indian National Space Promotion and Authorization Center
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
J-PAL	Abdul Latif Jameel Poverty Action Lab
LMIC	Low- and Middle-Income Country
MHT	Mahila Housing Trust
MIT	Massachusetts Institute of Technology
MSSRF	M. S. Swaminathan Research Foundation
NABARD	National Bank for Agriculture and Rural Development
NCD	Non-Communicable Disease
NCMRWF	National Centre for Medium Range Weather Forecasting
NDMA	National Disaster Management Authority
NHM	National Health Mission

Abbreviation

Abbreviation	Full Form
NIOHR	National Institute of Occupational Health Research
NPCCHH	National Programme on Climate Change and Human Health
NTU	Nanyang Technological University
PHC	Primary Health Centre
PIP	Programme Implementation Plan
SDMA	State Disaster Management Authority
SDRF	State Disaster Response Fund
SEWA	Self-Employed Women's Association
SFC	Sustainable Futures Collaborative
UHI	Urban Heat Island
UNEP	United Nations Environment Programme
UNICEF	United Nations Children's Fund
UTCI	Universal Thermal Climate Index
WBGT	Wet Bulb Globe Temperature

Glossary

Adaptive capacity

The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, take advantage of opportunities, or cope with consequences.

Adaptation

Making adjustments to anticipated climate changes and their impacts, depending on the capacities of systems, institutions, humans, and other organisms.

Climate intelligence

The collection, analysis, and application of historical, current, and predictive climate data to guide decision-making.

Early Warning System (EWS)

An integrated system that detects or forecasts a hazard, assesses potential impacts and communicates timely information to enable people and institutions to take protective action. For heat, an effective early warning system should connect forecasts with clearly defined health and response measures.

ERA5 Reanalysis

ERA5 is a global climate and weather dataset. It provides an hourly record of the atmosphere, land surface, and ocean waves from 1940 to the present. It is created by the European Centre for Medium-Range Weather Forecasts (ECMWF) as part of the Copernicus Climate Change Service.

Evapotranspiration

Evapotranspiration is the combined process where water moves from the land surface to the atmosphere. It adds up water evaporation from soils and water bodies with transpiration, which is water vapor released from plant leaves.

Exposure

The extent to which people, assets or systems are exposed to a climate hazard. For heat, exposure can vary according to geography, occupation, housing, time of day, duration of exposure and environmental conditions.

Heat Action Plan (HAP)

A coordinated plan designed to reduce the health and wider impacts of extreme heat through measures such as early warning, public communication, preparedness of health services, protection of vulnerable populations and inter-agency coordination. HAPs have become a key component of India's heat adaptation ecosystem.

Heat-health adaptation

The process of reducing the health risks associated with current and future heat exposure through changes in policies, systems, infrastructure, services, behaviours and technologies. It encompasses prevention, preparedness, response and longer-term resilience.

Heat-health vulnerability

The likelihood that an individual, population or health system will experience adverse health impacts from heat, based on the interaction between exposure, sensitivity and adaptive capacity.

Heat-related illness (HRI)

A broad range of health conditions caused or exacerbated by exposure to excessive heat. These range from relatively mild conditions such as heat cramps, heat rash, dehydration and heat exhaustion to severe conditions such as heatstroke. Heat can also worsen existing cardiovascular, renal, metabolic and other chronic conditions.

Glossary

Heat stress

The physiological strain experienced when the body is unable to adequately regulate its internal temperature in response to environmental heat. Heat stress is influenced by temperature, humidity, radiant heat, air movement, physical activity, clothing and individual characteristics.

Heatstroke

A severe, potentially life-threatening heat-related illness in which the body's core temperature rises to dangerous levels and thermoregulation fails. It requires urgent medical attention.

Occupational heat exposure

Exposure to excessive heat arising from workplace conditions, particularly among people engaged in outdoor or high-heat occupations such as agriculture, construction, transport, waste management and street vending.

Sensitivity

Sensitivity captures the physiological and social characteristics that determine the health consequences of a given exposure

Super El Niño

A Super El Niño is an exceptionally strong warm phase of the El Niño-Southern Oscillation (ENSO) cycle. It occurs when sea-surface temperatures in the central and eastern tropical Pacific Ocean rise by 2°C or more above average, severely disrupting global atmospheric circulation, weather patterns, and marine ecosystems.

Vulnerable populations

Groups that face disproportionately high risks from extreme heat because of greater exposure, higher sensitivity, lower adaptive capacity or a combination of these factors. These may include older adults, pregnant women, people living with chronic conditions, outdoor workers, low-income households and communities with limited access to healthcare, cooling and social protection.

Acknowledgements

This report is the result of a collective effort by India Health Fund (IHF), informed by the expertise, insights and experiences of individuals and organisations working across the heat and health ecosystem in India.

Innovators

IHF acknowledges the innovators who opened their work to us, sharing not only their achievements but also the challenges, and lessons learned from implementing heat adaptation solutions on the ground. We appreciate the contributions of Dr. Aarth Ramasamy and the team at M. S. Swaminathan Research Foundation (MSSRF); Tiffany Yeh, Ezia Materials; Nymisha Herrera Nimmagadda, Pranav Savanur and the Khushi Baby team; Akash Yadav, Andrew Schroeder and Natalie Ayers, from Climateverse; Gaurav Godhwani and Simonti Chakraborty from CivicDataLab; and Dr. Ritu Parchure, Prayas Energy Group.

Experts and Ecosystem Partners

The report also draws on discussions with experts and researchers who contributed their perspectives to strengthen our understanding of the evolving heat-health adaptation landscape. We acknowledge the Government officials and public institutions whose leadership, commitment and continued engagement are advancing India's response to the growing challenge of extreme heat.

We also thank the many partners and collaborators supporting the initiatives featured in this report, including National Institute of Medical Sciences (NIMS) University, Ashoka University, Swissnex, Asian Venture Philanthropy Network (AVPN), Prudence Foundation, Bayer Foundation, and the United Nations International Children's Emergency Fund (UNICEF) whose support has helped foster innovation, collaboration and knowledge generation across the climate and health ecosystem.

Authors

The report was conceptualised, researched, and authored by Dr Saurabh Mamtani, (Manager, Portfolio Team). Gargi Deshmukh, (Senior Associate, Communications) contributed to the refinement, editing and designing of the report.

Special Thanks to

We express our sincere gratitude to the contributors from India Health Fund team for their valuable support in the creation of this report. We would like to especially acknowledge India Health Fund's leadership and the team.

We would also like to thank our Ex-CEO Mr. Madhav Joshi for his continued support and encouragement.

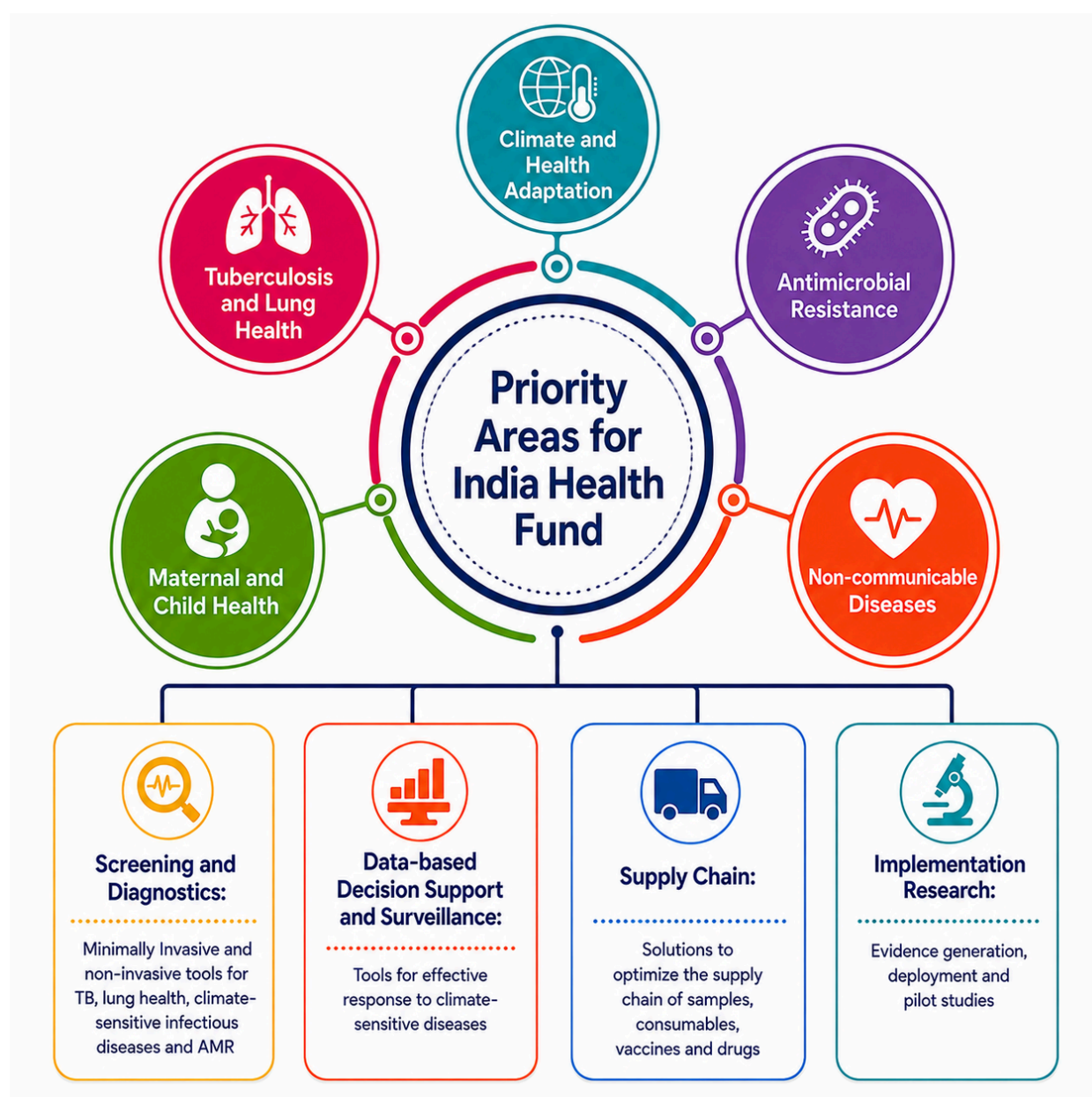
A special mention to Orange Health Digital for their valuable support with the design and illustrations of this report.

The views expressed in this report, are those of India Health Fund alone. The acknowledgement of any individual or organisation does not imply endorsement of the report's findings, conclusions or recommendations.

About India Health Fund

India Health Fund (IHF) aims to advance societal progress towards the elimination of infectious diseases and other public health risks with a particular focus on improving access to healthcare, equity, and preventing mortality. Since its founding in 2017 by the Tata Trusts as a not-for-profit organisation, IHF has been at the forefront in generating a catalytic effect on the financing of India's progress to meet the evolving landscape of public health challenges. IHF funds the development and de-risking of science and technology-based innovations along with supporting evidence-generation to bolster their lab-to-last-mile journey. IHF also builds partnerships and collaborations to strengthen health systems and improve health equity with scalable and sustainable approaches.

Since inception, IHF has continuously adapted to meet the evolving landscape of public health challenges. What began as a catalytic effort focused on tuberculosis (TB) and malaria has now expanded to also address other pressing challenges like the health impacts of climate change, antimicrobial resistance (AMR), lung health, and women's health, all while retaining a strong focus on communicable diseases. Throughout this journey, one thing has remained constant is the commitment to leverage cutting-edge technologies to improve early diagnosis and access to primary care, reduce infection transmission, bridge skill gap in healthcare workers and ensure scalability – all towards strengthening health systems and improving outcomes for those most in need.



Executive Summary

As the planet warms, extreme heat is increasing in India. Climate projections indicate that heat events are likely to become more frequent, intense and longer in duration in the coming years. The health impacts of heat extend far beyond only heatstroke. Extreme heat exacerbates cardiovascular, renal and metabolic conditions, increase risk during pregnancy, worsen comorbidities among older populations, expose outdoor and occupational workers to prolonged physiological stress, affects mental health and most importantly disrupts access to essential health services. In addition to health consequences, heat interacts with the environment and ecological systems, influencing disease-causing vectors to expand to new geographical regions, increasing the burden of infectious diseases.

Heat-related health burden remains under-recognised or often not attributed directly as a causal link to a health outcome, making it challenging to establish the true burden, evaluate interventions and make a compelling case for sustained investment. Heat exposure is highly uneven across geographies and populations. Adaptive capacity further remains unmeasured, making heat not only a climate hazard but also an issue of health equity.

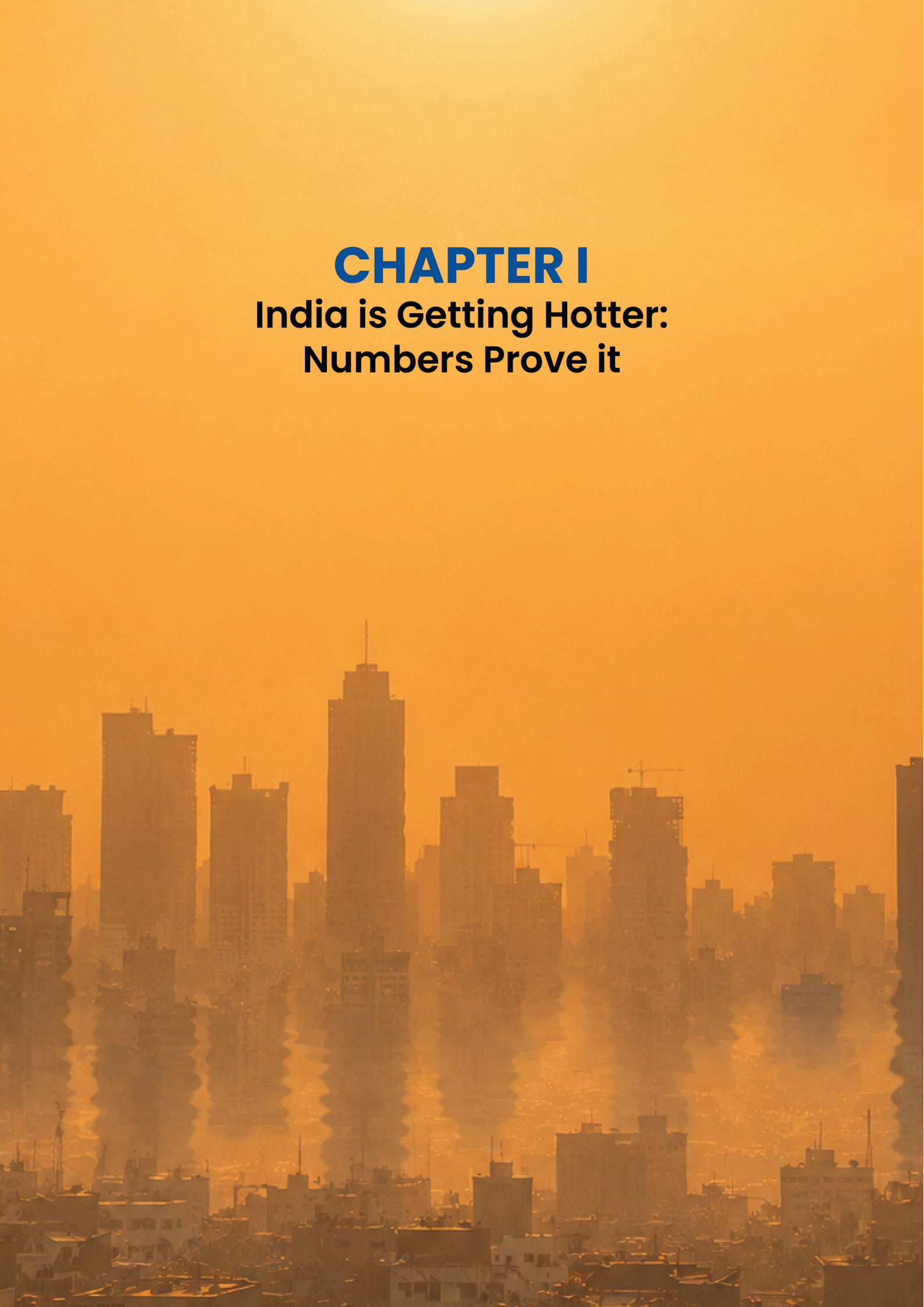
India has made considerable progress in responding to this challenge. Its heat adaptation ecosystem has evolved significantly over the past decade from a handful of pioneering local initiatives into a multi-layered landscape spanning policy and governance, research and evidence, civil society, technology and innovation, and financing and insurance. Heat Action Plans (HAPs) and early-warning systems have laid important foundations for preparedness and response. However, addressing heat requires more than issuing a temperature warning. A warning becomes a health intervention only when it triggers timely and targeted action by health systems, frontline workers, employers, communities and households. The challenge is no longer simply demonstrating that heat affects health but to close critical gaps between what is technically possible, what can be implemented at scale, and what can be demonstrated to deliver measurable health protection against extreme heat.

This report by India Health Fund examines the evolution of India's heat-health landscape and makes the case for moving from heat preparedness to integrated heat-health adaptation. Chapter I establishes the scale and trajectory of India's changing heat environment, while Chapter II examines the pathways through which heat affects health. It considers the interaction between heat and the environment, and the critical evidence gaps that need to shape India's future research agenda. Chapter III maps the evolution of Heat Action Plans and adaptation efforts whereas Chapter IV lays India's heat adaptation ecosystem across policy and governance, technology, innovation and financing. Highlighting Heat Adaptation Plans and efforts, we argue that India does not lack ecosystem actors or initiatives, but the challenge is to connect these efforts, address implementation gaps and build an integrated approach that links climate intelligence with health action, targeted protection, resilient infrastructure, behavioural interventions and health-system preparedness.

Innovation plays a central role to close the gap between what is technically possible, what can be implemented at scale, and what can be demonstrated to deliver measurable climate-health protection. Chapter V therefore examines key adaptation challenges and presents innovation exemplars across cooling, digital intelligence, health-system strengthening, behavioural solutions and evidence generation. The examples featured in the report demonstrate that innovation is not limited to the technology but also encompasses new delivery models, data systems, community-led approaches, evidence-generation mechanisms and locally appropriate solutions.

However, innovation alone cannot deliver scale. Financing plays a critical enabler of the transition from promising solutions to sustained impact. Chapter VI highlights distinctive financing challenges associated with heat-health adaptation and calls in for a more integrated financing architecture that can support innovation through development, validation, adoption and scale.

India has moved significantly beyond recognising heat as a seasonal hazard and has built important foundations for preparedness. The next phase requires a shift towards measurable, integrated and scalable health adaptation. The opportunity is not simply to respond better to hotter summers, but to build health systems and communities that are resilient to a hotter future. India Health Fund, through its catalytic funding approach is poised to help accelerate this transition, from evidence to innovation, from innovation to implementation, and from implementation to scale. India Health Fund is committed to orchestrating a stronger heat adaptation ecosystem; one that connects research, innovation, and implementation, while generating the evidence needed to inform policy and strengthen resilience within public systems.



CHAPTER I

India is Getting Hotter: Numbers Prove it

Chapter I: India is Getting Hotter: Numbers Prove it

Heat at the Earth's surface has intensified over the past century as a result of climate change. Sustained high temperatures push thermal conditions beyond the range in which the human body can function normally. Extreme heat occurs when temperatures rise well above what is normal for a given place and season, to levels hazardous for people and ecosystems (Mora et al., 2022; Romanello et al., 2025).

The hazard is rarely limited to a single hot day. High humidity, urban heat island effects, and high nighttime temperatures cause heat to accumulate over successive days and night. When this elevated thermal load persists for several days to weeks, it is classified as a heatwave. In operational terms, the India Meteorological Department (IMD) defines a heatwave as a period of abnormally high daytime temperatures. (India Meteorological Department, n.d.; Kumar et al., 2020)

Heatwaves occur principally during pre-monsoon period between April and June and, in some years, extend into July (Krishnan et al., n.d.). Because India spans several climatic zones, heatwave criteria are applied only after IMD weather station's maximum air temperature exceeds a zone-specific absolute threshold: at least 40°C in the plains, or at least 30°C in hilly regions (India Meteorological Department, n.d.). Once that threshold is breached, IMD declares a heatwave on either of the two criteria:

1. A departure from normal by 4.5°C to 6.4°C constitutes a heatwave and a departure exceeding 6.4°C as a severe heatwave. (India Meteorological Department, n.d.)
2. Based on actual maximum temperature: when maximum air temperature of 45°C or above is recorded it is considered a heatwave and 47°C or above as a severe heatwave. (India Meteorological Department, n.d.)

Coastal areas are treated separately, a heatwave may be described when the departure from normal is 4.5°C or more, provided the actual maximum temperature is at least 37°C (India Meteorological Department, n.d.).

These criteria must be met at a minimum of two stations within a meteorological sub-division on two consecutive days, with the heatwave is declared on the second day (India Meteorological Department, n.d.; Kumar et al., 2020).

Heatwaves are among the most serious manifestations of climate change for human health and are among its most immediate hazard. India's temperature records indicate that the frequency of its heatwave occurrence has been intensifying. Ten of the country's fifteen warmest years since 1901 occurred between 2011 and 2025, and the decade 2016–2025 was the warmest on record (World Bank Climate Change Knowledge Portal, n.d.; Krishnan et al., n.d.). The year 2024 remains the warmest year in the series, with an annual average mean surface air temperature 0.65°C above the 1991–2020 long-term average of 32.04°C.

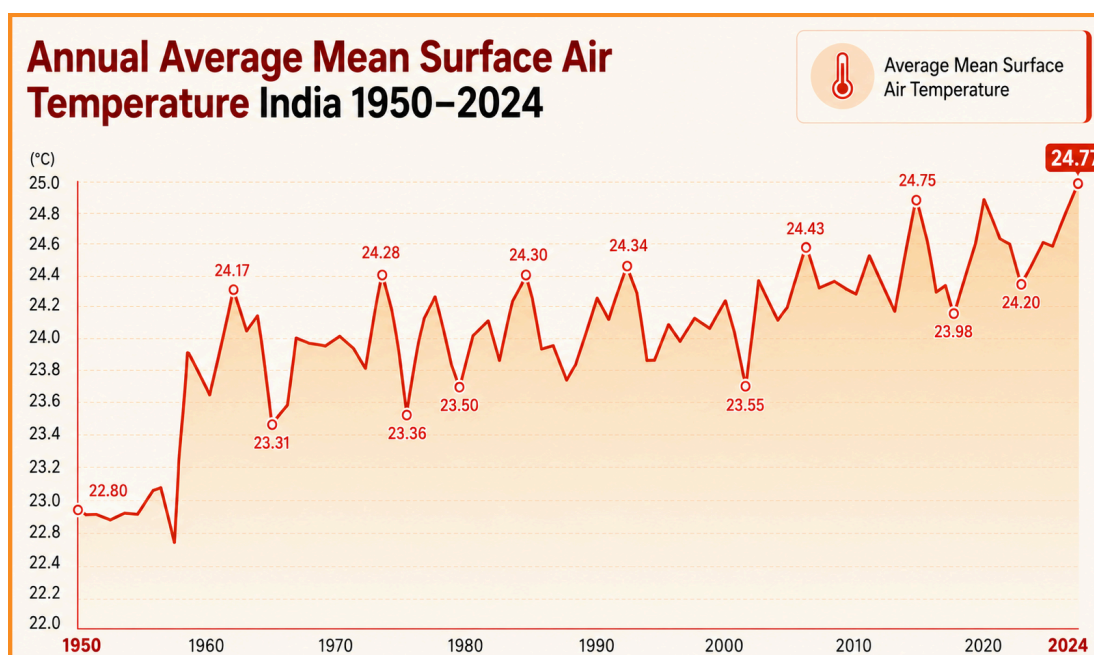


Figure 1.1: Graph showing average mean surface air temperature in India (1950–2024) | Data Source: World Bank, analysis: India Health Fund)

The same warming signal is shown in Figure 1.2 which highlights the annual anomalies against the 1951–2023 long-term average of 32.04°C. Through the 1950s, 1960s, and 1970s, annual temperatures were generally lower than the long-term average. The 1980s and 1990s marked a transitional period, with temperatures fluctuating around the baseline and showing no consistent long-term pattern. From 2000 onward, the warming trend shifts clearly, with most years recording temperatures above the long-term average. The highest departures were observed around 0.65°C above the baseline. Together with Figure 1.1, these observations indicate that warming has been sustained over time rather than occurring as isolated events, with each recent decade warmer than the preceding one. (World Bank Climate Change Knowledge Portal, n.d.)

individual in an outdoor environment (Di Napoli et al., 2021; Naskar et al., 2024).

UTCI data were obtained from ERA5-HEAT reanalysis dataset (Copernicus CDS), covering the Indian subcontinent at an approximate spatial resolution of 25 km for the period of 1990 to 2025. For each location and each day, we retained the daily maximum UTCI, since peak afternoon exposure is the period of greatest risk to human health (Di Napoli et al., 2021; Thermal Comfort Indices Time-Series Derived from ERA5 Reanalysis, n.d.).

Two analyses were then undertaken. First, each day was classified into one of the standard UTCI heat stress categories: strong (32–38°C), very strong (38–46°C) or extreme (above 46°C) (Naskar et al., 2024).

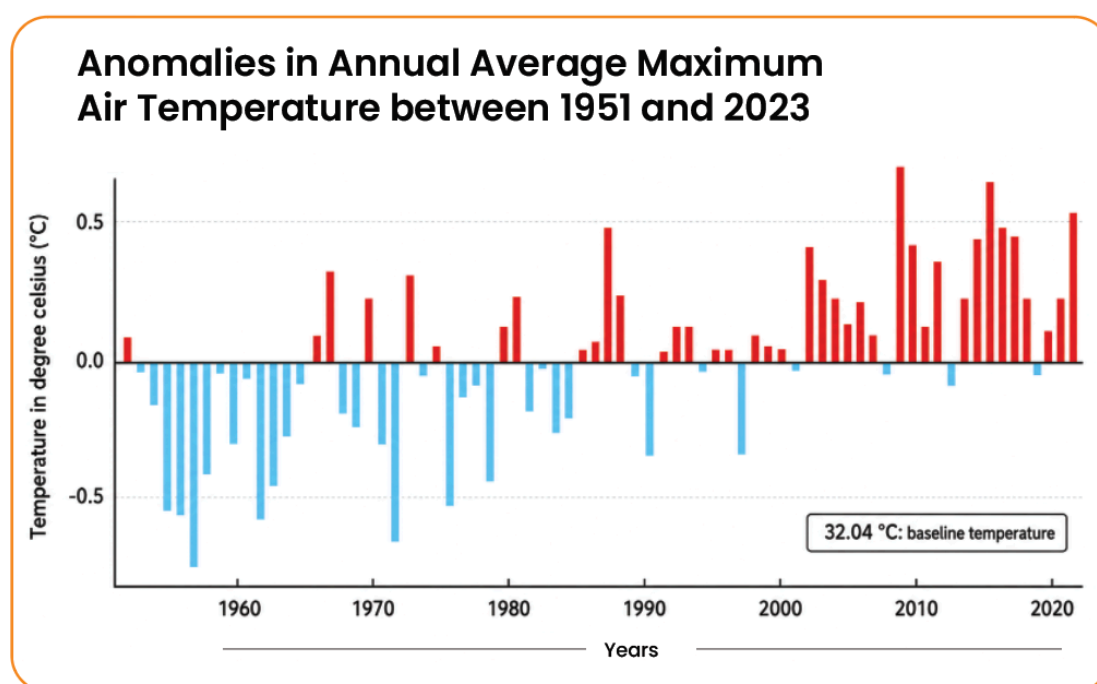


Figure 1.2 Graph showing anomalies in annual average maximum air temperature (1951-2023, Data Source: World Bank, analysis: India Health Fund)

To examine how heat stress is distributed across India and how it is changing, we analysed the Universal Thermal Climate Index (UTCI) data. We chose UTCI as it integrates ambient temperature, wind speed, mean radiant temperature (quantification of heat exchanged between a human and the surrounding environment), and relative humidity with human thermophysiological models (these models study thermoregulation and maintenance of homeostasis in the human body). The UTCI calculates an equivalent of ambient temperature (°C) to accurately estimate the actual physiological heat load experienced by an

The number of days in each category was calculated for each year and then averaged across three periods: the 1990s, the 2000s, and 2010–2025. The analysis shows where physiologically stressful conditions occur and how frequently they are experienced. Second, we assessed whether UTCI has been rising or falling at each location across the full 36-year period, using the Mann-Kendall test with Sen's slope. It reports the rate of change in degrees Celsius per decade and distinguishes a genuine trend from ordinary year-to-year variation. Locations where the trend was statistically significant ($p < 0.05$) are indicated by stippling.

Together, these two analyses separate two different questions that are often conflated in heat planning: where heat stress is already severe, and where it is becoming more severe. The answers do not necessarily identify the same locations, and this distinction is important for the effective allocation of adaptation resources.

The decadal maps establish the scale of existing heat stress exposure (figure 1.3). Strong heat stress is near-ubiquitous across peninsular and coastal India, where UTCI values are in the range of 32–38°C and occur for approximately 200 to 300 days each year and have done so consistently in every decade since the 1990s.

Very strong heat stress (38–46°C), the range in which physiological strain becomes serious for healthy adults, extends across much of central and northern India and, here the maps show clear intensification, with the affected area expanding and deepening across the Indo-Gangetic plain and central India between the 1990s and the most recent period. Extreme heat stress above 46°C remains largely confined to a narrow dry-heat corridor across western Rajasthan, where it becomes more concentrated from the 2000s onward. These are exclusive categories rather than cumulative ones, so where the count of strong-stress days falls while very-strong days rise, conditions have not eased: days have moved up a band.

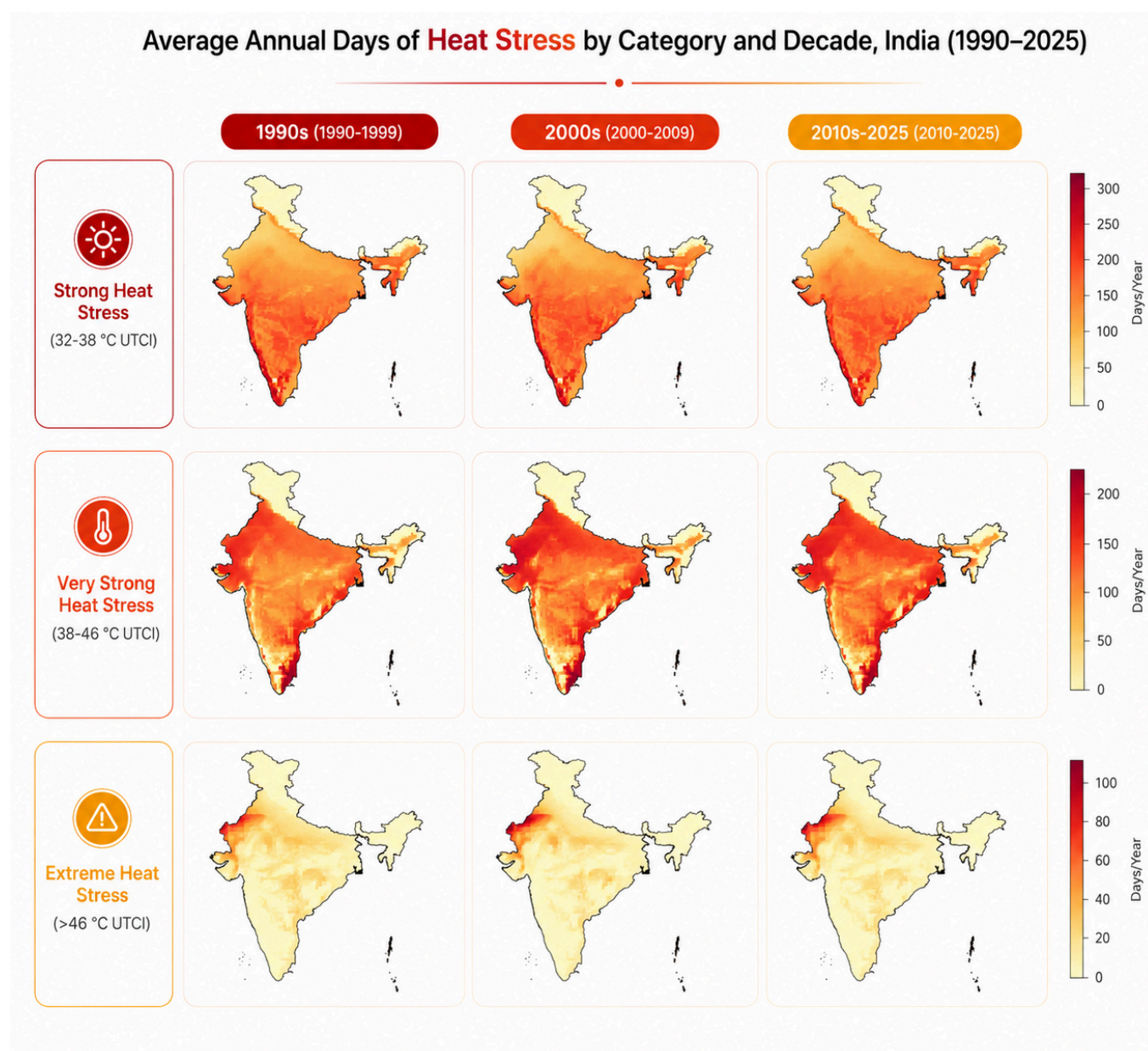


Figure 1.3 Average annual days of heat stress by heat category and decade in India from 1990–2025. Data Source: UTCI, Copernicus CDS, analysis: India Health Fund

The trend map on the other hand shows that statistically significant warming is concentrated not within the already-hot core but along its margins including Jammu & Kashmir and Ladakh, the north-eastern states, eastern central India across Jharkhand, Odisha and Chhattisgarh, interior Maharashtra and Telangana, pockets along the west coast and Western Ghats, and the Andaman and Nicobar Islands. By contrast, across Gujarat, Rajasthan and parts of Madhya Pradesh, UTCI warming trends are weak, non-significant, or in places slightly negative, even though these areas carry the country's highest absolute heat-stress day counts. Their risk is best described as chronically severe rather than accelerating.

This supports a two-track approach to adaptation. Sustained investment in heat-health is required in regions where heat exposure is already extreme, particularly in the north-western corridor and the central belt, where the burden is high and persistent irrespective of trends. At the same time, monitoring, early warning and health system preparedness need to extend into the north, north-east and eastern-central India, where absolute risk today remains comparatively lower but the measured trend indicates these regions are moving toward conditions that are harsh and where housing, health services and public awareness have not been built around heat.

Our findings are consistent with, and reinforced by, independent evidence on India's heatwave activity.

Annual UTCI Trend across India, 1990–2025

(Mann-Kendall / Sen's slope; dots = significant at $p < 0.05$)

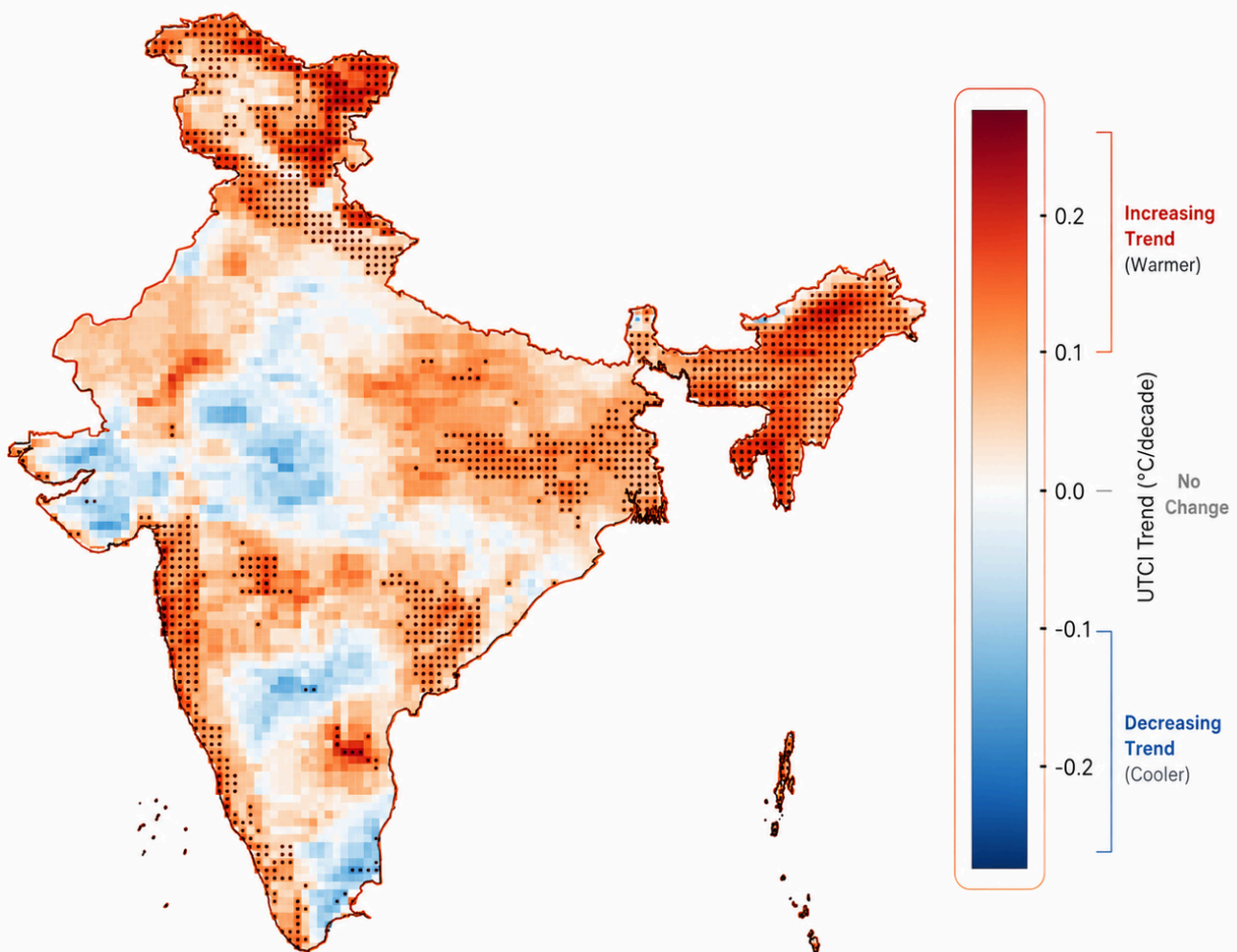


Figure 1.4: Annual UTCI trend across India (1990–2025). Data Source: UTCI, Copernicus CDS, analysis: India Health Fund

- Since **1985, 31 of the 39 years have recorded temperatures above the long-term average** (de Bont et al., 2024)
- The number of states experiencing heatwave conditions **rose from 9 to 23 between 2015 and 2020** (Krishnan et al., n.d.; Ravindra et al., 2024)
- India's ten major cities alone recorded **168 distinct heatwave events between 2008 and 2019** (de Bont et al., 2024)

Studies also show that in urban areas, temperatures and health risks soar due to the urban heat island effect. To get an insight we compared ambient air temperatures in different built environments, and the results are presented in figure 1.5. Commercial and built areas in cities were 5°C to 10°C warmer than surrounding areas, likely increasing the heatwave intensity and the associated health risks. These localised amplifications are the consequences of human activities including (Islam et al., 2024):

- **Thermal Mass Absorption:** Dense concrete, asphalt, and building materials absorb high levels of solar radiation during the day and re-emit it as longwave thermal radiation at night.
- **Deforestation & Deficit Cooling:** Drastic reductions in vegetative cover and canopy layers limit shading and eliminate ambient evapotranspirative cooling.

- **Anthropogenic Waste Heat:** Heat is continuously injected into the urban canopy layer by human activities including vehicular emissions, industrial processes, and Heating, Ventilation and Air Conditioning (HVAC) systems.
- **Morphological Trapping ("Urban Canyons"):** Tall, densely packed urban structures create urban canyons that obstruct convective wind flow and trap longwave radiation.
- **Aerosol Radiative Forcing:** High concentrations of urban air pollution create a localised greenhouse effect, retaining heat on the island (The Synergies of Heat Stress and Air Pollution and Its Health Impacts, n.d.-a).

The evidence presented in this chapter highlights both the scale of India's warming trend and the growing extent of the heat hazard. Heat is no longer confined to traditionally hot regions but is increasingly affecting parts of the country that were historically considered climatically moderate. Our analysis shows that several of these emerging regions are already exhibiting statistically significant warming trends, signalling a broadening geography of heat risk. These findings underscore that heat is becoming a nationwide hazard with serious risk to public health, requiring adaptation strategies that anticipate future risk rather than respond only to historical patterns.

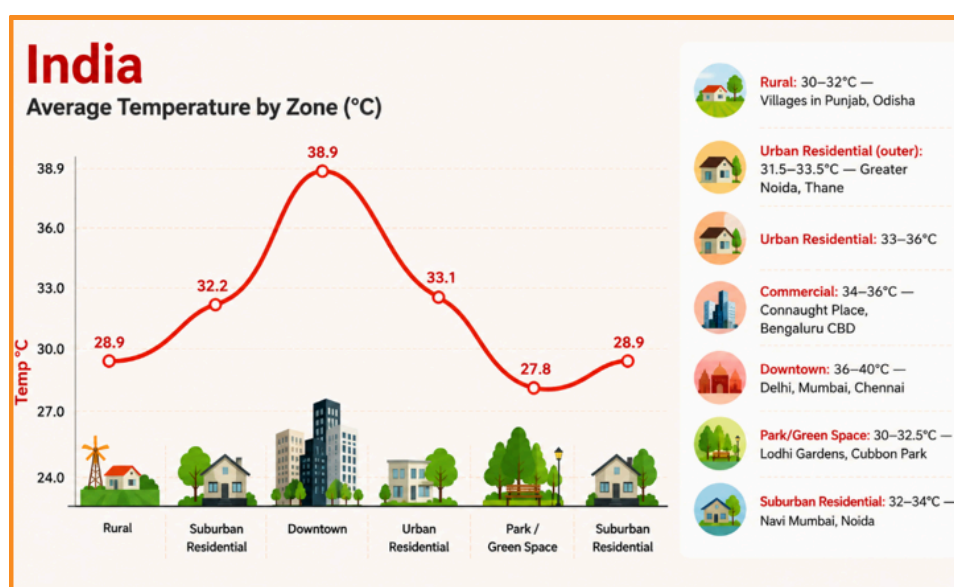


Figure- 1.5: UTCI temperatures across different built environments (Source: IMD ambient air temperature data)

The evidence we have is already an indictment on our lack of intention and action to prevent the devastation from climate change. What we do not yet know only makes the urgency of addressing the gaps greater.

CHAPTER II

Heat and Health



Chapter II: Heat and Health

Once regarded as an environmental or meteorological phenomenon, heat is now recognised as a major public health risk affecting morbidity, mortality, health system performance, labour productivity, and economic resilience.

India is among the countries most vulnerable to the health impacts of extreme heat. Rising temperatures, more frequent and prolonged heatwaves, increasing humidity, and persistently warmer nights are altering patterns of heat exposure across both urban and rural settings (Krishnan et al., n.d.; Kumar et al., 2020; Mora et al., 2022; Ravindra et al., 2024). The country's large population, extensive informal workforce, rapid urbanisation, and existing burden of communicable and non-communicable diseases further amplify this risk. Recent vulnerability assessments by CEEW estimate that 57% of India's districts, home to nearly three-quarters of the population, face “high” to “very high” heat risk, reflecting the combined influence of climatic hazards, population exposure, and underlying social and biological vulnerabilities (Prabhu et al., 2025).

This chapter examines the pathways through which extreme heat affects human health, beginning with the physiological mechanisms of thermoregulation and heat stress. It then explores the health consequences of heat across population groups, examines the biological, occupational,

and infrastructural factors that shape vulnerability in India, and discusses the broader implications of extreme heat for disease patterns, health systems, and future research. Together, these sections illustrate why strengthening heat-health adaptation must become a central component of financing climate resilient interventions.

2.1 Heat and the Human Body: The Clinical Continuum

Heat stress represents the physiological strain that occurs when the body's internal heat production and external heat gain exceed its capacity to dissipate heat. As thermoregulatory mechanisms become overwhelmed, core body temperature rises, homeostasis is disrupted, and multiple organ systems begin to experience physiological stress (Gagnon et al., 2026).

Heat-related illness is therefore best understood as a clinical continuum that begins with mild, reversible symptoms and, if unrecognised or untreated, can progress to multi-organ failure and death (Gagnon et al., 2026). Recognising this continuum is critical because it creates opportunities for early intervention; treating heat-related illness only as a catastrophic event delays care until the point at which intervention may no longer be effective.

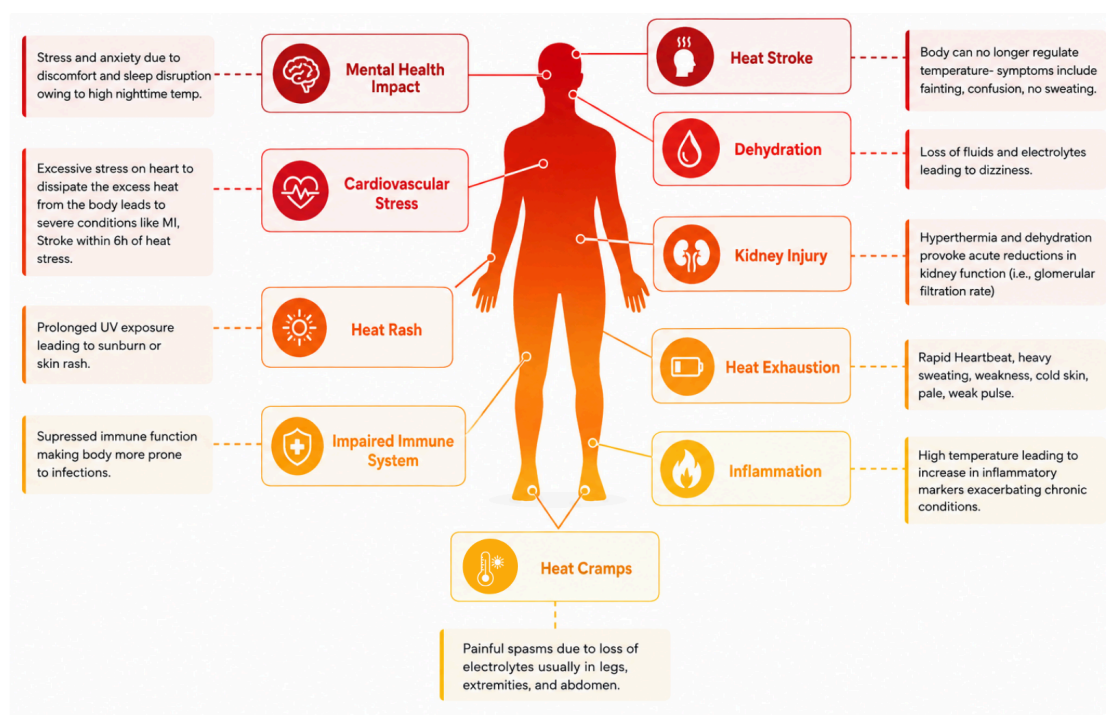


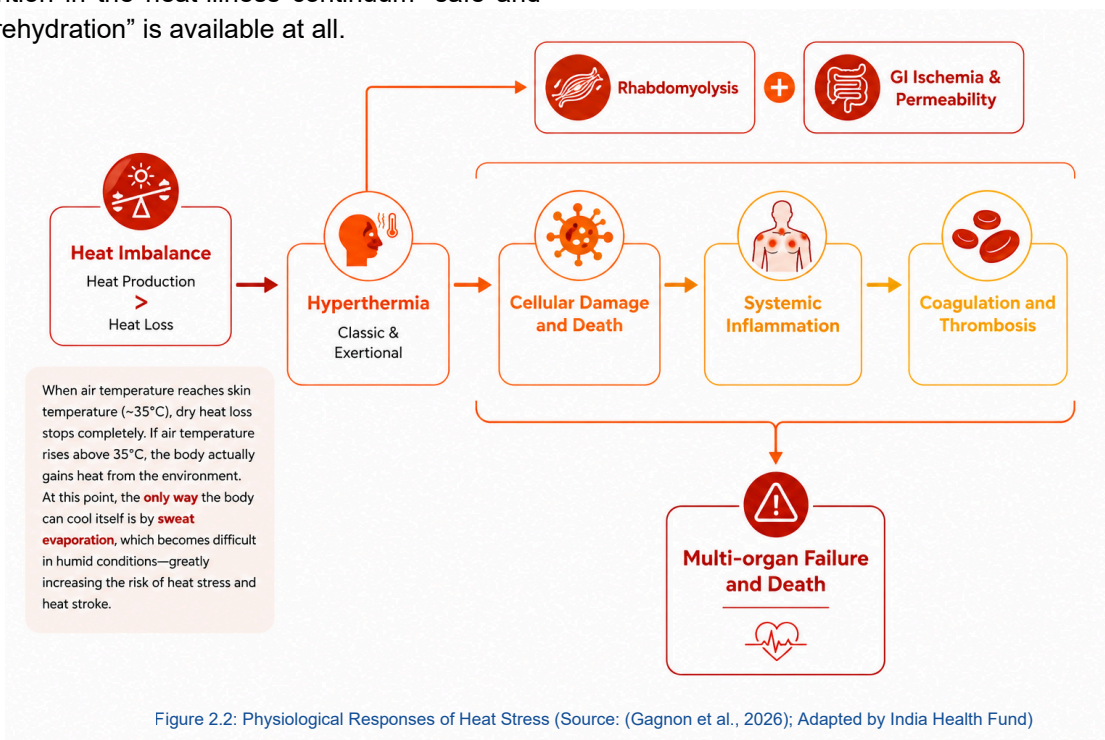
Fig 2.1: Clinical Continuum of Heat-related Illness (Source: India Health Fund)

The earliest manifestations of heat exposure are often mild and reversible. Occasional exposure can produce heat rash or oedema, while excessive perspiration or fluid loss under dry-heat conditions can result in dehydration and electrolyte disturbances. These disturbances may produce neuromuscular manifestations such as cramps, muscle twitching, paraesthesia, headache or syncope. At this stage, symptoms can ordinarily be reversed through hydration, electrolyte correction, and rest (Gagnon et al., 2026; Romanello et al., 2025).

However, the effectiveness of the first line intervention “water”, depends on whether individuals have equitable, safe and adequate access to it. Dehydration is a principal driver of heat-related hospital admissions, yet more than 25% of India's population lacks access to potable water; 58% of households do not treat drinking water before consumption, rising to 66% in rural areas (NFHS, n.d.). These figures determine whether the simplest intervention in the heat-illness continuum “safe and timely rehydration” is available at all.

piloerection, and muscle cramping (Gagnon et al., 2026). At this stage, management remains relatively straightforward: rest, moving from the heat to a shaded environment, and slow oral rehydration with electrolytes can help restore thermoregulatory function. The clinical significance of heat exhaustion lies in its reversibility, representing a critical opportunity to intervene before physiological deterioration becomes life-threatening (Heat and Health, n.d.; Sorensen & Hess, 2022).

If adequate cooling does not occur at this stage, heat exhaustion can progress to heat stroke, at which point hospitalisation becomes essential. Heat stroke is defined by a core temperature exceeding 40.5°C (104°F) and is potentially fatal (Heat and Health, n.d.; NCDC | MOHFW, n.d.-a; Sorensen & Hess, 2022). Its clinical danger is compounded by the difficulty of recognising it promptly: presentation can vary according to the dominant symptom, and altered mental status, the presence or absence of sweating, tachycardia, tachypnoea and headache may be



Persistent thermal exposure and dehydration can ultimately result in heat exhaustion, which represents the critical window between early heat-related illness and heat stroke. Sustained fluid loss through perspiration in humid conditions, or through cutaneous and respiratory routes in arid conditions, causes thermoregulation to begin failing. Core body temperature rises, and increasing physiological strain is placed on the body's organ systems. Heat exhaustion typically presents with a rapid pulse, faintness, headache, nausea, cold clammy skin with

attributed to conditions such as sepsis, myocardial infarction, cerebrovascular accident, or acute renal failure (Gagnon et al., 2026).

Its clinical danger is compounded by the difficulty of recognising it promptly: presentation can vary according to the dominant symptom, and altered mental status, the presence or absence of sweating, tachycardia, tachypnoea and headache may be attributed to conditions such as sepsis, myocardial infarction, cerebrovascular accident, or acute renal

failure (Gagnon et al., 2026). Misdiagnosis in the early stages is therefore common. Correct management requires monitoring of rectal core temperature and rapid cooling at approximately 0.2°C per minute in a supervised clinical setting, alongside concurrent slow rehydration (NCDC | MOHFW, n.d.-b).

Each 1°C rise in outdoor air temperature has been associated with a 35–45% increase in heat stroke risk (de Bont et al., 2024). During recent periods of extreme heat, India has reported nearly 48,000 suspected heatstroke cases and approximately 159 deaths in a single year (State of the Climate in Asia in 2024, n.d.).

The progression from mild heat illness to heat stroke underscores the importance of prevention and early intervention. Heat stroke is a preventable and treatable condition. When heat stress is recognised and addressed at the stages of dehydration or heat exhaustion, its progression to severe illness can be substantially reduced. (Sorensen & Hess, 2022) Mortality from a condition that is both preventable and treatable therefore reflects not only the availability of therapeutic knowledge, but also whether heat illness is recognised in time and whether people can access the water, cooling and healthcare required to interrupt its progression.

Prevention consequently requires coordinated action across communities, local public health authorities, labour organisations and healthcare providers. It also requires infrastructure that accommodates the diverse needs of populations exposed to heat. The clinical continuum of heat-related illness thus extends beyond the individual patient: the point at which a person enters that continuum, and whether they can safely move back from it.

2.2 Risk Framework for Heat and Health

The Intergovernmental Panel on Climate Change (IPCC) conceptualises climate risk through the interaction of **hazard, exposure and vulnerability**, with vulnerability encompassing both sensitivity and adaptive capacity. Applied to heat, hazard refers to the intensity, duration and frequency of thermal extremes; **exposure** refers to the populations, assets and systems located within the affected geography; **sensitivity** captures the physiological and social characteristics that determine the health

consequences of a given exposure; and adaptive capacity refers to the physiological, infrastructural, institutional and financial resources available to moderate those consequences (Das et al., 2020; The Fifth Assessment Report of the IPCC | UNFCCC, n.d.). Assessing these dimensions together is essential to understanding India's shifting public health risks from heat: the same thermal hazard can produce radically different health outcomes depending on differences in sensitivity and adaptive capacity.

India's demographic heterogeneity makes this variation particularly important. A population exceeding 1.4 billion (Press Note Details: Press Information Bureau, n.d.), differentiated by age, geography, socioeconomic position, education, employment and gender, does not experience a common heat risk. An ambient temperature that a healthy adult may be able to physiologically regulate can be poorly tolerated by people such as outdoor workers, pregnant women, older adults, children and low-income populations or people living with communicable or non-communicable diseases. Men and women may also experience heat stress differently because of both biological and social factors. At the geographic level, urban heat islands can intensify exposure through elevated absolute temperatures and suppressed nocturnal cooling, while rural populations may face more constrained access to hydration, cooling and medical care.

While Chapter I has established the nature of the hazard and the range of heat exposure in India, the sections that follow examine the remaining two dimensions of Vulnerability as described in the IPCC framework: sensitivity and adaptive capacity.

2.3 Sensitivity

Although sensitivity differs substantially between population groups, the biological pathways through which heat affects the human body provide a common foundation. Heat exposure can produce cellular and systemic dysfunction, with thermoregulatory failure affecting immune function and dehydration altering systemic inflammatory responses. These effects can amplify existing respiratory, and other chronic conditions such as Cardiovascular, Kidney, and Metabolic Disorders (CKMD) (de Bont et al., 2024; Gagnon et al., 2026; Zhang et al., 2024).

Sleep disruption is another most widely reported consequences of heat exposure and extends beyond fatigue, with implications for physical and mental health (Fritz, 2026). The mental health consequences of heat are less visible but increasingly being recognised as

psychological stress associated with sustained thermal discomfort is being linked to anxiety, mood disorders and cognitive impairment (Fritz, 2026; Romanello et al., 2025; Zhang et al., 2024). The physical, mental and social effects of heat are therefore extensive, although the evidence base remains constrained by gaps in systematic research, outreach and intervention.

2.3.1 Renal and Cardiovascular Pathways

The kidneys are particularly sensitive to sustained heat exposure because dehydration, reduced renal perfusion, direct tubular cell injury and inflammation can collectively precipitate acute kidney injury (AKI) (Gagnon et al., 2026). AKI is the second most common cause of excess hospital admission during heat events (Chapman et al., 2020). Among workers experiencing heavy exertional heat exposure, rhabdomyolysis can further compound renal injury (de Bont et al., 2024; Tamim et al., 2025). Available data indicate that **15% of outdoor workers routinely exposed to heat stress develop AKI**, although this figure is likely to underestimate the burden among agricultural and informal workers who may have limited access to clinical diagnosis (Chapman et al., 2020; Zhang et al., 2024).

Repeated cycles of heat exposure and dehydration, followed by partial recovery from AKI,

can contribute to **heat stress nephropathy**, a progressive condition ultimately leading to chronic kidney disease (CKD) (Gagnon et al., 2026). Each **1°C rise in outdoor temperature is associated with a 3% increase in kidney-related mortality** (de Bont et al., 2024).

Cardiovascular disease represents a similarly important pathway through which heat exposure can translate into excess mortality. It is the leading cause of death in India, accounting for 3,121,036 deaths annually approximately one quarter of all mortality nationally. The Indian epidemic is also distinguished by its early age of onset: more young adults aged **18–35 years** present with cardiovascular disease or its risk factors than in any comparable population. Projections indicate that by **2036, 65% of India's population** will be affected by one or more clinical risk factors or comorbidities including hypertension, dyslipidaemia, diabetes and obesity each of which is both a precursor to cardiovascular disease and a morbid condition in its own right (Soundararajan et al., 2025; VizHub - GBD Results, n.d.).

Pathophysiology of Heat Stress on Kidneys

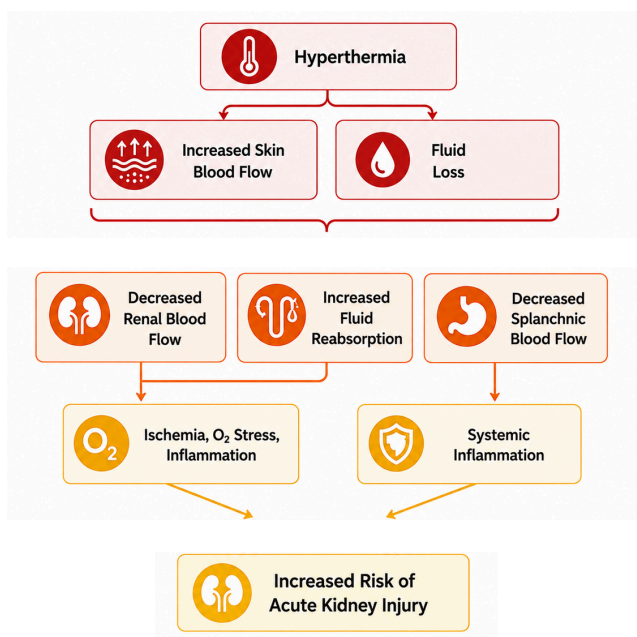


Figure 2.3: Physiology of Heat Stress on Kidneys (Source: (Gagnon et al., 2026); Adapted by India Health Fund)

Pathophysiology of Heat Stress on CVD

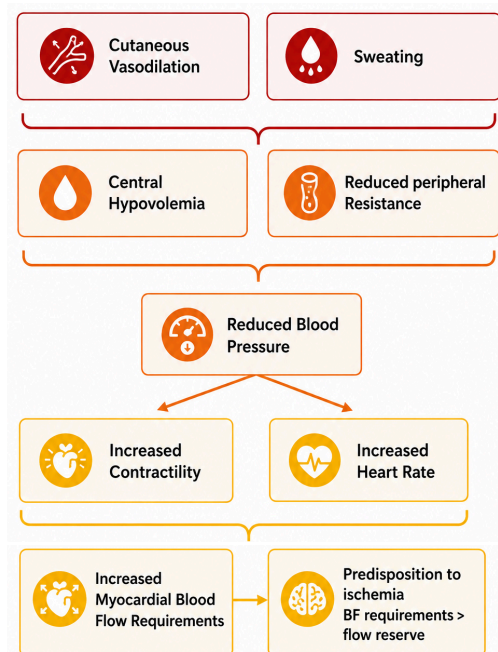


Figure 2.4: Pathophysiology of Heat Stress on cardiovascular diseases. (Source: (Gagnon et al., 2026) Adapted by: India Health Fund)

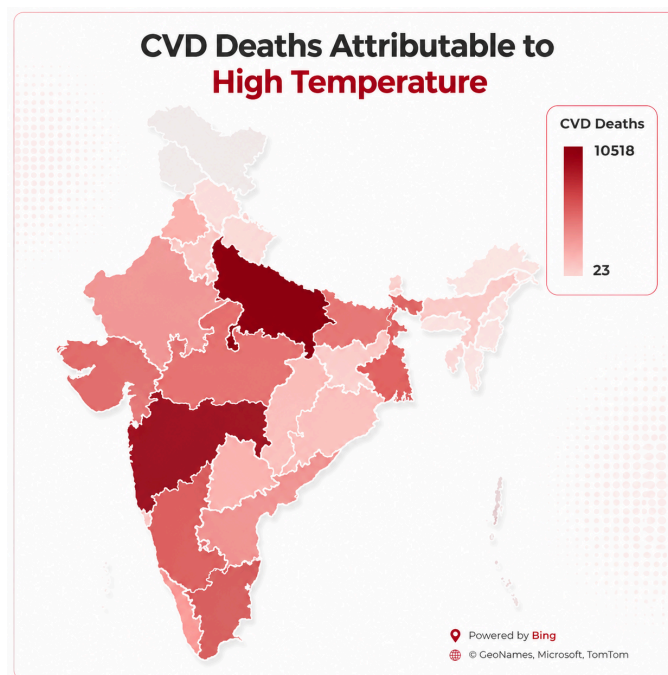


Figure 2.5: Projected prevalence of cardiovascular risk factors and comorbidities in India. (Source: (VizHub - GBD Results, n.d.); Analysis by India Health Fund)

Figure 2.5 illustrates this projected trajectory. Its significance for heat and health lies in the convergence of two expanding risks: the population accumulating cardiometabolic risk is also entering decades of potential occupational and environmental heat exposure. These burdens can therefore converge in the same individuals over the same period. In India, this underlying clinical risk is itself shaped by environmental and behavioural factors, including sedentary and inactive behaviours, automobile dependence, unhealthy diets, tobacco and alcohol consumption, and air and noise pollution, several of which also co-locate geographically with thermal stress.

Extreme heat can further compound cardiovascular risk through haemodynamic stress. As the body attempts to dissipate heat, cardiac output rises to sustain cutaneous perfusion and sweat production.

This increased cardiovascular demand, combined with fluid loss, contributes to the tachycardia and dehydration associated with heat exhaustion and can impose a workload that a compromised myocardium may be unable to sustain (Gagnon et al., 2026).

Epidemiological evidence indicates that each **1°C increase in ambient temperature is associated with a 2.1% increase in all-cause cardiovascular mortality, a 2.8% increase in mortality from heart disease and a 3.8% increase in fatal stroke**. During heatwaves, excess cardiovascular mortality risk rises to 11.7% (de Bont et al., 2024) (Soundararajan et al., 2025). Given the size of India's underlying cardiovascular disease burden, even modest relative increases in risk can translate into substantial absolute mortality.

Age-wise Forecasted Non-Communicable Disease Burden Distribution, India

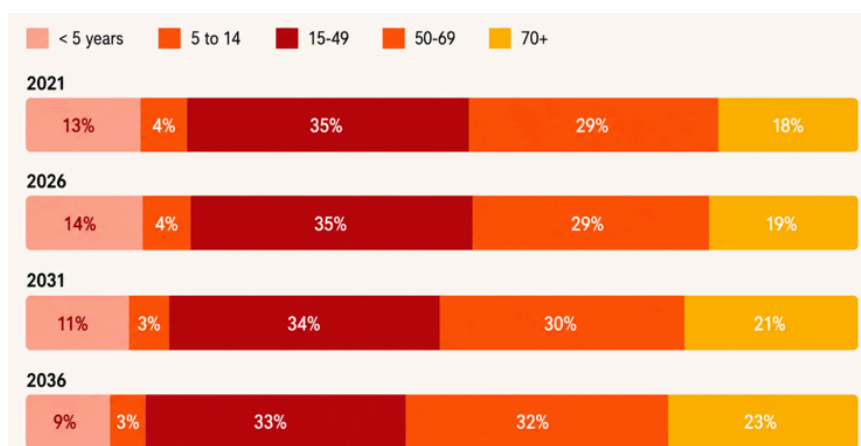


Figure 2.6 Age-wise, forecasted non-communicable disease burden distribution (Source: India Health Fund)

2.3.2 Pregnancy and Heat

Pregnancy represents another period of heightened physiological sensitivity to heat. Pregnant women have a lower heat tolerance threshold, as cardiac output is already elevated to meet fetal nutritional and oxygen demands while the maternal body must simultaneously dissipate the metabolic heat generated by fetal growth and activity.

Three mechanisms are thought to contribute: additional fetal metabolic heat production, the insulating effect of pregnancy-associated fat deposition that slows cooling, and higher baseline cardiac output (Dey et al., 2025; Kc & Vaezghasemi, 2025; Romanello et al., 2025). Together, these factors may make pregnant women measurably more sensitive to heat stress at lower ambient temperatures, particularly under humid conditions.

Heat stress during pregnancy is associated with complications including pre-eclampsia, gestational diabetes, miscarriage, low birth weight, preterm birth, growth restriction and stillbirth, while first-trimester heat exposure has been associated with developmental abnormality. Quantified estimates include a 26% higher risk of preterm birth associated with heat exposure, 12% higher odds of stillbirth per 1°C rise in ambient temperature, and a 1.54-fold increased risk of gestational diabetes per 1°C rise (Lakhoo et al., 2025). These estimates derive substantially from high-income country settings with different baseline maternal health profiles. Their applicability to the Indian context therefore requires empirical verification rather than assumption, particularly given differences in maternal health, occupational exposure, housing, cooling access and healthcare access.

2.3.3 Older Adults

Age is another major determinant of physiological sensitivity to heat. In India, adults over the age of 60 constituted **8.6% of the population in Census 2011**, (Census Tables | Government of India, n.d.) and this share is projected to reach approximately **12%, or 193 million people, by 2030** (Ageing and Health India, n.d.).

Ageing affects multiple physiological functions required to maintain heat balance. The onset of sweating is delayed because of a blunted thermoregulatory response; cardiac output declines and perfusion to organs, particularly the skin, is reduced; sweat glands produce less sweat; thirst sensation diminishes, reducing fluid intake; and total body water reserves contract. As a result, heat stress thresholds are lower among older adults and are lowered further by comorbidities (Gagnon et al., 2026).

The presence of two or more NCDs, called multimorbidity, can compound this sensitivity either through the underlying pathology or medications that impair thermoregulation. Heat-related mortality among older adults has risen by approximately 68% over the past two decades (Romanello et al., 2025) (Falchetta et al., 2024). Whether this global pattern occurs at an equivalent magnitude in India cannot presently be established because the requisite India-specific analyses have not been conducted. This represents a significant evidence and operational gap given the scale of projected population ageing.

2.3.4 Occupational Exposure

Occupational exposure represents a distinct dimension of heat sensitivity because exposure is often prolonged, physically demanding and difficult for workers to avoid. Up to **75 percent of India's workforce, or 380 million people**, dependent on heat-exposed labour. With heat-exposed work contributing to nearly half of the country's Gross Domestic Product (GDP), making it extremely vulnerable to job losses ("Climate Investment Opportunities in India's Cooling Sector," 2022).

During summer, workers in agriculture, construction, transport and mining routinely experience exposures exceeding standardised safe temperature thresholds, beyond which, ideally, the work should be suspended or managed through structured work–rest cycles (Ioannou et al., 2022). Evidence from the city of Hyderabad illustrates the gap between exposure and workplace protection: only 15–20% of gig workers had access to cooling facilities, rehydration, rest areas or shade, while just 6% used heat-protective clothing or footwear (Impact of Extreme Heat on Gig Workers: A Survey Report – Telangana Gig and Platform Workers Union, n.d.).

Min and Max WBGT Temperature (Apr-Jun) by Occupation

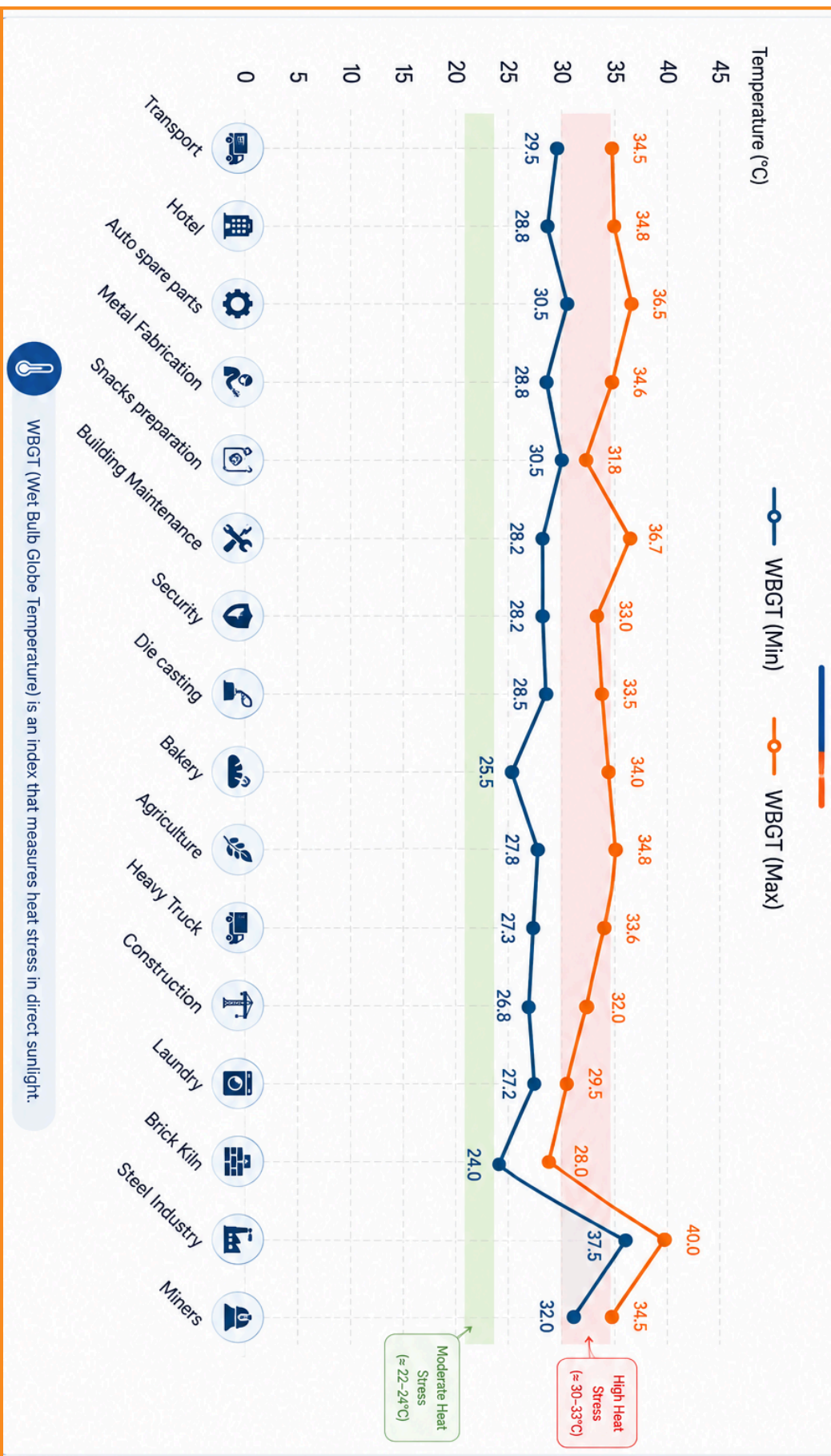


Figure 2.7: Observed WBGT exposure ranges by occupational category against safe, moderate and critical thresholds. The green band denotes WBGT levels considered safe for sustained work; the unshaded mid-zone indicates moderate heat stress requiring work-rest cycling; and the red band denotes critical thresholds beyond which work should cease to prevent heat-related illness. It demonstrates that several occupational categories operate routinely within and above the moderate-stress zone during the summer months. These thresholds have particular implications for adolescents, women and older workers, people with comorbidities, and seasonal migrant labourers, whose physiological or social vulnerabilities can further reduce their capacity to tolerate sustained heat exposure. (Data Source: NFHS, ILC; Analysis: India Health Fund)

Risk is further compounded when physical outdoor labour coincides with exposure to chemicals or particulate matter (Tamim et al., 2025).

Heat exposure is not confined to outdoor occupations. For indoor workers, risk is determined by working conditions rather than ambient temperature alone, including humidity and ventilation in confined spaces and the intensified thermal environments found in culinary and industrial sectors.

2.4 Adaptive Capacity: Knowledge, Geography and Health System Access

In India, adaptive capacity is constrained at three interconnected levels: what the surveillance system is able to record, what the health system is equipped to deliver, and how far an exposed population is from the infrastructure and services required to respond.

The first constraint is epistemic, HRI and the heat exacerbated illnesses are not systematically accounted for in burden-of-disease estimates or routine epidemiological data (de Bont et al., 2024; MoHFW Government of India NCDC-NPCCHH, n.d.; Zhang et al., 2024). When heat is not consistently captured as an exposure or contributing factor in morbidity and mortality data, the health system has limited visibility of its true burden. This creates a feedback problem: surveillance determines what a health system can see, and what it can see shapes where resources, preparedness and interventions are directed. A system that does not systematically record heat-related health effects cannot reliably quantify the burden it is expected to address or allocate resources against it (Gkouliaveras et al., 2025).

The second constraint is health-system capability. The gaps occur in the resources, processes and infrastructure required to act on the knowledge that exists. The majority consequence of heat stress emerge when hydration is delayed, potable water is unavailable, cooling facilities and materials are absent, patients are not transferred to adequately resourced facilities in time, heat stroke is misdiagnosed, or conditions such as acute kidney injury go undiagnosed.

At each point, a condition that could have been managed early can progress into severe morbidity or death (Dube et al., 2025; Scheelbeek et al., 2021). The third constraint is geographic access. The infrastructure required to identify and treat heat stroke within the first 30 minutes remains inaccessible to a large proportion of the vulnerable population. Available data indicate that 68% of Primary and Community Health Centres in India lack cooling infrastructure or heat-ward capacity (NCDC | MOHFW, n.d.-a).

Walking times to the nearest PHC or CHC range from under an hour in accessible districts to over 2,000 minutes in remote areas (Patil et al., 2025) nor can it be assumed that construction sites, mining operations or urban health facilities are equipped with the knowledge, cooling capacity and materials required to manage a heat-stress casualty.

These limitations extend beyond formal health facilities. There is limited national evidence on the preparedness of communities, occupational sites and healthcare providers for heat-induced health emergencies. Adaptive capacity is therefore not only constrained, but it also remains unmeasured. This makes it difficult to determine whether existing heat-health interventions are reaching the populations most exposed, whether health facilities can respond effectively when those interventions fail, and where investments in infrastructure and preparedness would have the greatest impact (Dube et al., 2025).

2.5 Heat and Environment

Rising temperatures also alter the ecological systems through which infectious diseases are transmitted and maintained. Changes in temperature can reshape microbial environments, favouring organisms that are able to adapt to warmer conditions while reducing the diversity and stability of existing microbial communities. From soil and water to the atmosphere and the human gut, microorganisms play fundamental roles in ecosystem functioning and human health. As these environments warm, the microbial conditions in which food is produced, water systems function and infectious diseases circulate can also change (Meher et al., 2025; Mora et al., 2022).

The epidemiological consequences are increasingly measurable. A 1°C rise in temperature is associated with an estimated 13% increase in dengue transmission risk, (Anikeeva et al., 2024; Damtew et al., 2023) while malaria-transmitting mosquito species are establishing at higher altitudes that were previously outside their thermal range. Warmer water and soil can also favour bacteria including *Salmonella* species and *Vibrio cholerae*, increasing the potential for foodborne and waterborne disease. In India, these risks may be further compounded during heatwave periods by limited access to safe and adequate drinking water, potentially increasing exposure to contaminated water and contributing to a changing landscape of waterborne infections, including infections caused by antimicrobial-resistant pathogens (Anikeeva et al., 2024; Meher et al., 2025; Mora et al., 2022).

Additionally, heat-mediated changes in microbial ecology and antimicrobial resistance (AMR) can erode the effectiveness of antibiotics already compromised by historical overuse and misuse, narrowing the therapeutic options available to control infectious morbidity and mortality. Heat adaptation therefore cannot be framed solely as a response to an acute seasonal emergency. It must also account for the slower environmental changes through which rising temperatures can alter the epidemiology of infectious disease and the pharmacological foundations on which its treatment depends (Hacopian et al., 2025; Meher et al., 2025; Mora et al., 2022; Yi et al., 2024).

Urbanisation introduces an additional pathway. Increasing urban density means that more households are living and working within smaller and more concentrated spaces. During periods of extreme heat, people may seek relief in shared, cooled indoor environments. Where these spaces have poor air circulation, however, they can facilitate the transmission of respiratory infections. At the same time, intense heat can affect immune function, while changes in temperature and environmental conditions can alter the circulation of respiratory pathogens such as influenza viruses (Meher et al., 2025).

This is particularly consequential for India, which is undergoing a prolonged epidemiological transition. The burden of non-communicable disease has increased sharply, but infectious diseases have not been displaced; instead, climate change and environmental disruption can reinforce existing infectious disease risks

(VizHub - GBD Results, n.d.). Heat consequently has the potential to compound rather than replace existing health burdens, increasing the complexity of an already heterogeneous public health landscape.

2.6 Evidence Gaps and the Research Agenda

The evidence assembled in this report provides a strong basis for recognising heat as a public health exposure but remains incomplete for quantifying its full contribution to India's disease burden. Part of the difficulty is methodological. Heat is neither a discrete exposure, such as a vector that transmits an infection, nor a chronic stimulant such as nicotine with a well-characterised dose–response relationship to chronic disease.

Its effects can vary according to duration, intensity, timing, humidity, individual susceptibility, concurrent exposures and adaptive capacity. Establishing the causal architecture linking heat to the re-emergence of infectious diseases and to chronic disease trajectories and situating these pathways within the hazard–exposure–vulnerability framework therefore requires methodological approaches that are not yet standardised.

Generating this causal knowledge will require longitudinal cohort studies that track heat exposure across the everyday lives of demographically diverse populations, with dedicated sampling of the groups identified in section 2.3 as highly sensitive. Heat exposure should also be embedded as a variable within routine disease surveillance and facility-level data collection on heat-attributable admissions. Without these capabilities, planning will remain largely reactive: resource-intensive, poorly targeted and difficult to assess for cost-effectiveness.

It is important to note that while we wait for the evidence to build up, we also need to act now. Delayed action carries a double cost: allowing existing health risks to worsen beyond the reach of systemic adaptation while new and emerging risks develop without being adequately observed.

CHAPTER III

Heat Action Plans and Adaptation Efforts



Chapter III: Heat Action Plans and Adaptation Efforts

A foundational shift in India's approach to extreme heat has evolved with the recognition of heatwaves and lightning within the country's disaster management framework. For most of the past decade, heatwaves were treated as state-specific disasters rather than centrally notified ones. Individual states for example, Odisha, Rajasthan, Telangana, and Andhra Pradesh incorporated heatwave management into their disaster management plans, allowing them to draw on up to 10% of their State Disaster Response Fund (SDRF) allocation for heat stress interventions. This provision was available for locally significant disasters that were not included in the centrally notified list (Singh et al., 2024). This state-led approach was formalised following the National Disaster Management Authority's (NDMA) 2016 guidelines on heatwave management, building on earlier state declarations dating back to 2015 (Reports & Studies | NDMA, n.d.).

The 16th Finance Commission subsequently recommended, in late 2025, that heatwaves and lightning be added to India's centrally notified list of disasters. The recommendation that would unlock more substantial central funding, including the main SDRF allocation and the State Disaster Mitigation Fund for both preparedness and response, rather than the limited 10% carve-out that states have relied on to date (Finance Commission, India :, n.d.). Recently, the centre formally acted on this recommendation, by, expanding the notified disaster list from 12 to 14 categories to include heatwave and lightning (Press Information Bureau, n.d.). This marks a substantive shift from the current framework moving India from a patchwork of state-level heat provisions toward a nationally recognised funding architecture for heat-health preparedness and response.

Building on the success of Ahmedabad's pioneering Heat Action Plan, India now has over 300 Heat Action Plans (HAPs) at the state, district, and city levels (How We Build Scientific Heat Action Plans with Indian Cities | CEEW, n.d.). The NDMA aims to expand this to 500 plans, recognising that many states and cities still rely on basic advisory measures for heat prevention rather than comprehensive, actionable strategies. The NDMA has also proactively encouraged CSO partners such as Council on Energy Environment and Water, Mahila Housing Trust, etc.

To provide technical assistance in the development of HAPs (How Can Heat Action Plans Make Thane a Heat-Resilient City?, n.d.; Varanasi Heat Action Plan - Mahila Housing Trust, n.d.).

However, the quality and implementation capacity of HAPs varies enormously. We believe the following systemic gaps hinder the desired outcomes that HAPs could deliver:

- HAPs often carry an oversimplified understanding of the heat hazard, without taking into account the socio-economic, ecological, infrastructural and institutional capacities of the communities and implementation agencies like ULBs, Municipal Corporations and district health authorities.
- HAPs remain underfunded for effective implementation.
- They often lack strong legal foundation and are insufficiently interconnected with cross-cutting sectors such as health care delivery pathways or Health Action Plans.
- Capacity building efforts remain siloed in sectors and continue to underestimate the needs at the grassroots level.

A well-designed HAP should adopt a ward-level, micro-scale approach to identify and address local patterns of heat vulnerability. It should also be integrated with existing planning processes, including National Health Mission (NHM) health action plans and other relevant sectoral strategies, to ensure coordinated implementation. Importantly, HAPs must be intervention-oriented, translating risk assessments and data analysis into clear, actionable measures across both short- and medium-term time horizons. While short-term measures such as early warning dissemination, access to cooling spaces and resources, provision of safe drinking water, and health system preparedness are relatively well established in many HAPs, mechanisms to ensure its delivery remains weak. Moreover, medium-term structural interventions remain underdeveloped. These interventions include urban planning, infrastructure improvements, and nature-based cooling measures, essential for building long-term resilience and reducing the impacts of recurring heat events.

The effectiveness of HAPs ultimately depends on whether proposed measures are practical, affordable, and acceptable for the populations most affected.

This creates a series of implementation and policy dilemmas that technical assistance partners are increasingly expected to help resolve. For example, adjusting outdoor working hours can reduce heat exposure for construction workers, street vendors, and other informal workers, but may also lead to income losses unless accompanied by livelihood protections or compensatory mechanisms. Similarly, governments require cooling interventions that are not only effective in reducing heat stress, but also affordable for low-income households, energy-efficient, low-carbon emitting, and scalable across diverse urban and rural contexts. Another challenge lies in determining the level and type of investment needed to improve thermal comfort in public spaces, transport systems, markets, schools, and other high-exposure urban environments, where infrastructure upgrades often compete with other development priorities. Stakeholders also emphasise that solutions should be integrated into HAPs in ways that are operationally feasible and financially sustainable, rather than remaining isolated pilot initiatives.

India's heat adaptation architecture is gaining momentum, with more institutions sharing responsibility to expand HAP coverage and with newer financing frameworks. The fragmented planning, outreach and implementation need concerted efforts that will yield better health outcomes. Our research and analyses suggest that HAPs must evolve beyond tertiary, reactive, analysis-heavy documents into practical, locally contextualised and financially backed action-plans that span short-term emergency response as well as medium-term structural transformation.

Residential settlements can't be changed immediately but how do we work with the same settlements and improve their living conditions and adaptive capacity during Heatwave is where policy and implementation efforts should be focused.

CHAPTER IV

Current Heat Adaptation Ecosystem and the Case for an Integrated Heat-Health Adaptation Approach



Chapter IV: Current Heat Adaptation Ecosystem and the Case for an Integrated Heat-Health Adaptation Approach

4.1 Mapping India's Heat Adaptation Ecosystem

India's heat adaptation ecosystem has evolved significantly over the past decade from a handful of isolated experiments into a multi-layered ecosystem that has spread across multiple regions of the country. Our mapping has identified over 120+ organisations operating across seven functional domains: policy and governance, research and evidence generation, civil society and advocacy, technology and innovation, finance and insurance, development finance and philanthropy and community-level implementation.

4.1.1 Policy and Governance

At the policy and governance level, evolution is gradual yet functional. For example, the role of IMD has shifted from issuing temperature observations to providing district level forecasts and colour-coded heat warnings, supporting local decision-making. The introduction of the Heat Index, which incorporates both temperature and humidity, has strengthened risk assessment rather than relying solely on dry-bulb temperature. NDMA on the other hand has moved from disaster response coordination to developing national standards. It provides policy frameworks planning guidelines, and advisory structures that inform state and city HAPs while the execution and implementation of these policies have been devolved to the SDMA, municipal corporations, and Urban Local Bodies.

Within the health sector, the Ministry of Health and Family Welfare (MoHFW) runs the clinical response through the National Programme on Climate Change and Human Health (NPCCHH). Under NPCCHH heat-related morbidity and mortality surveillance moved onto the digital IHIP platform in 2023, enabling daily reporting right from the PHC level to secondary and tertiary hospitals (MoHFW, NPCCHH, n.d.).

Despite significant institutional progress, gaps in communication within these institutions are the key constraint to operating as an integrated system.

NDMA sets planning standards but the technical assistance for SDMA on implementing them is missing. IMD's role ends once warnings are issued. The MoHFW collects daily data on HRIs and deaths, but this information reaches disaster management only through administrative reporting, with states required to integrate health-sector heat plans into broader climate-health action plans and share them with SDMAs.

The India Cooling Action Plan reflects a similar disconnect. Although cooling is one of the most effective measures to reduce heat exposure, the plan is managed by the Ministry of Environment, Forest and Climate Change and focuses on energy efficiency, refrigerant management, and long-term cooling demand over a twenty-year period. Its targets are measured in cooling demand without looking at externalities like health outcomes, and it operates independently of both disaster management and public health systems. (NCDC | MOHFW, n.d.-b)

Different ministries and departments oversee complementary components, managing different aspects of the same hazard, each with its own mandate, timeline, and reporting structure. There is no single framework or institution that owns the response outcomes or the governance and coordination. This fragmentation becomes even more complex when the downstream actors from district and urban local bodies are involved. Effective coordination across them is becoming increasingly important to translate individual ministerial efforts into a coherent and targeted implementation response.

4.1.2 Research & Evidence

Research and evidence generation has moved from framing heat as general climate concern to the most significant public health concern of climate change, establishing clearly which populations are exposed and also improving understanding of the pathways through which heat affects humans.

Research institutions such as the Indian Institute of tropical meteorology (IITM) and the National Centre for Medium Range Weather Forecasting (NCMRWF) anchor meteorological science, whose data forms the backbone of everyone working in the ecosystem. While government research institutions have been leading applied research, translating complex research and data into actionable insights for public health interventions.

For example, one of the strongest areas of research for protecting the population from extreme heat risk is through adequate prevention of occupational heat exposure. The Indian Council of Medical Research (ICMR), through its National Institute of Occupational Health Research in (NIOHR) in Ahmedabad, has built a growing evidence base on occupational heat exposure, informing prevention guidelines and various protocols for occupational heat health risks. (ICMR-NIOHR Official Website - ICMR-NIOHR, n.d.) In addition to this Centre for Public Policy at IIM Bangalore has produced a spatiotemporal analysis of heat stress exposure across India from 1981 to 2023, revealing not only intensification over time but a sharp caste-based gradient in who bears the occupational heat burden (Shah et al., 2025).

International institutions and scientific partners are working in select pockets, alongside the domestic research institutions: Emory University co-developed the Ahmedabad plan, Harvard's Lakshmi Mittal South Asia Institute is running sensor-based worker heat exposure monitoring through its Community HATS project, and J-PAL South Asia is conducting randomised evaluations of parametric heat insurance for informal workers (COMMUNITY HATS • The Lakshmi Mittal and Family South Asia Institute, n.d.).

Currently, it is important to consolidate the evidence being generated and strengthen the pathways through which research and evidence inform surveillance protocols, clinical guidelines, and frontline worker training to make heat a standing part of health service delivery rather than a seasonal alert.

4.1.3 Civil Society Organisations (CSOs)

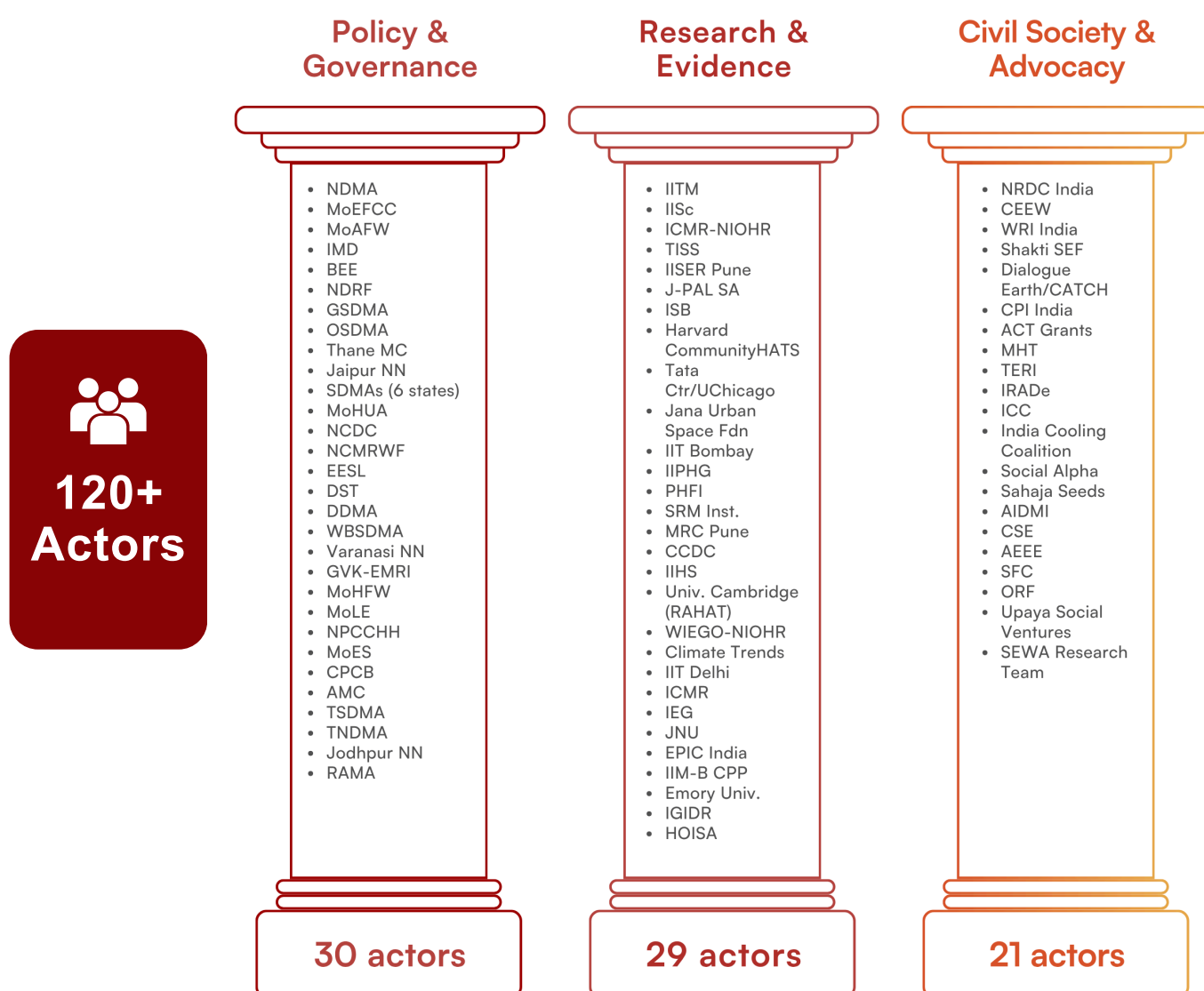
CSOs have acted as the connective tissue of the ecosystem simultaneously conducting policy-relevant research, co-designing community interventions, and emphasising extreme heat as an emerging governance priority.

Three archetypes are actively working in this space:

- First is the Grassroots implementers providing ground level technical assistance to deploy, demonstrate feasibility and scale the heat-health adaptation solutions. A notable example in this is the Mahila Housing Trust (MHT) wherein they translated the cool roofs model into direct implementation for low-income women across the states of Gujarat, Rajasthan and Uttar Pradesh, running ward-level heat vulnerability assessments that feed into heat action plans and rolling out parametric insurance for economic cushioning of vulnerable households during heatwaves (Mahila Housing Trust, n.d.; Inclusive Finance and Extreme Heat: How Small Loans and Parametric Insurance Can Help Vulnerable Populations Manage Through Deadly Heat Waves. April 2023 - Mahila Housing Trust, n.d.).
- The second archetype consists of policy think tanks which provide the analytical capability required to strengthen heat response. Their work spans climate risk modelling, exposure and vulnerability mapping, and drafting of plans that can be adopted by government departments and officials.; A notable example is the Council on Energy, Environment and Water (CEEW) that developed India's Climate Vulnerability Index, mapping all districts by exposure and adaptive capacity, and has actively supported the development of Thane Heat Action Plan (How We Build Scientific Heat Action Plans with Indian Cities | CEEW, n.d.).
- The third group comprises of catalytic funders which provide the financing tools that public systems need but cannot commission themselves, these organisations de-risk innovations and build evidence needed for wider public health adoption. For example, the India Health Fund's support to Khushi Baby for developing a Climate Health Vulnerability Index for Rajasthan exactly demonstrates how catalytic capital for de-risking the innovation expands government's capacity for informed decision making using an AI-based decision-support tool that combines climate exposure, population sensitivity and adaptive capacity into vulnerability scores at village, block and district level (Khushi Baby: IHF, n.d.).

CSO supported research and pilot deployments have produced strong local evidence, but very little of it has been taken up into state budgets or standing government programmes, leaving civil society to sustain interventions that should have transitioned into public systems.

India's Heat Adaptation



Ecosystem 2025-26

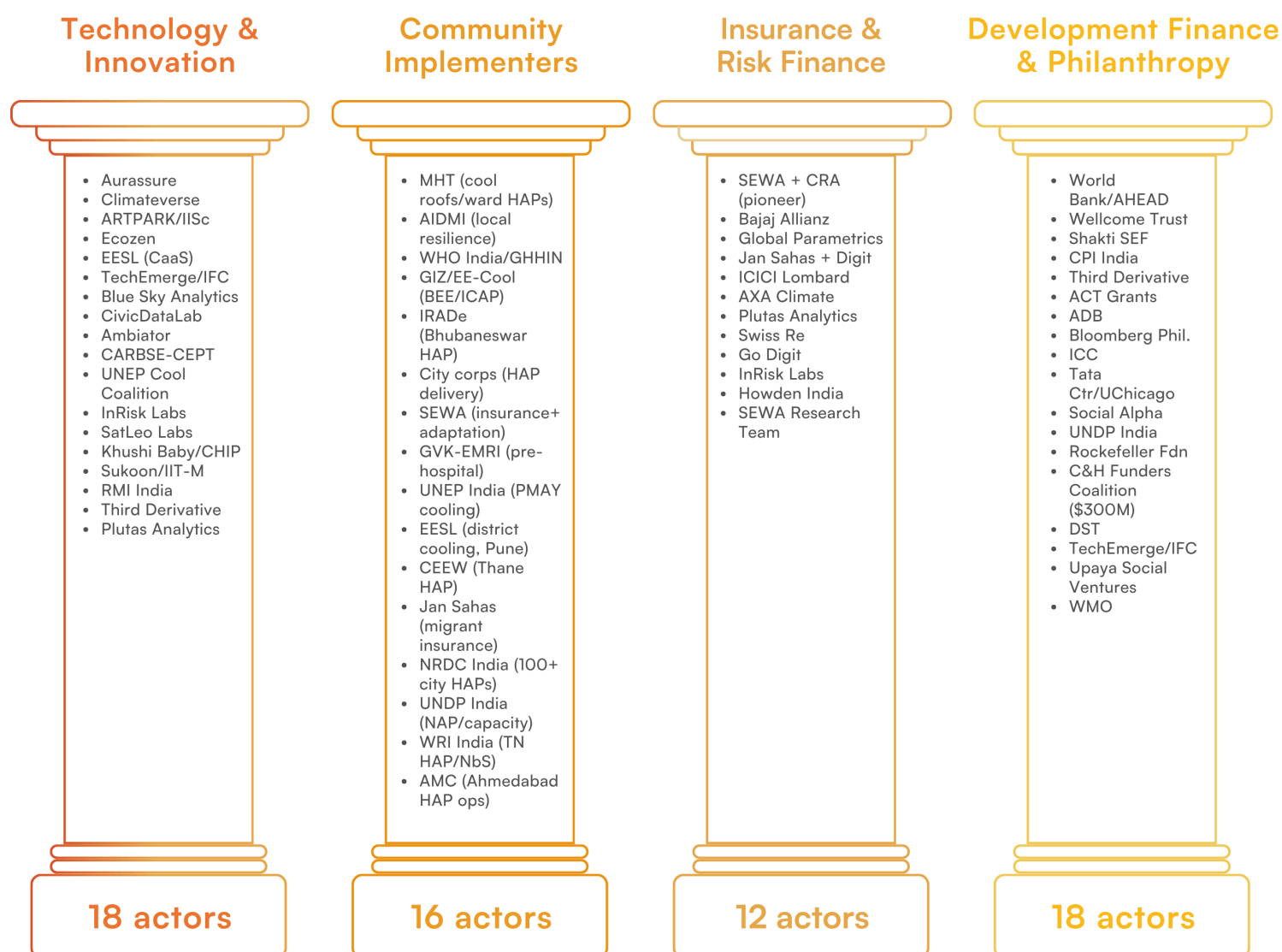


Figure 4.1: India's Heat Adaptation Ecosystem Stakeholder and Technology Landscape: 2025-26 (Source: Individual Organisation Websites; Collated by: India Health Fund)

4.1.4 Technology and Innovation

The technology layer is the newest and the fastest moving segment of the heat adaptation ecosystem. It is also distinctly shaped within India's geographical context with innovators responding to challenges that are unique, such as sparse ground data, unreliable power supply, low ability to pay, etc. Three broad groups of innovations are visible in this domain:

- The first group looks at revolutionising mapping heat stress. Official meteorological infrastructure measures temperatures at station and district level, but exposure varies sharply within a single city, between a shaded residential colony and an unshaded industrial cluster a few kilometres away. Such variations are often invisible to conventional systems, limiting the ability of municipal governments to target interventions. Addressing this challenge, Aurassure has deployed over 2,000 street-level IoT sensors, fused with satellite imagery and proprietary AI-physics models, to generate high-resolution heat stress intelligence for city governments, raising ₹25 crore in a Pre-Series A round in 2025. (Aurassure, n.d.). SatLeo Labs, incubated at IN-SPACe in Ahmedabad, is developing a constellation of microsatellites with sub-10-metre thermal imaging resolution built specifically for urban heat island mapping, a first at this scale (Thermal Intelligence from Space | Satleo Labs, n.d.).
- The second group reimagines cooling technologies for vulnerable populations. Ambiator's refrigerant-free evaporative system operates at 80% lower electricity consumption than conventional air conditioning, and the company is developing a Heat Resilience Shelter model envisaging 5,000 off-grid public cooling shelters for migrant workers. (Ambiator - Cooling without Warming the Planet., n.d.) Ecozen Solutions applies the same logic but with an AI-powered, battery-less solar cold room now used by over 100,000 small landholder farmers across seven states, addressing heat-driven post-harvest losses that convert directly into lost income and food insecurity (Ecofrost - Solar Powered Cold Storage Room Manufacturer in India - Ecozen | Ecozen, n.d.).
- The third focused on protecting the body for occupations where the workplace itself cannot be cooled: steel, cement and construction sites cannot be enclosed and thus require workers to

remain in the high-temperature environments. Sukoon, spun out of IIT Madras, has developed BluPULSE a low-cost cooling jacket that helps outdoor workers maintain their body temperatures at safe levels (Cooling PPE for the World's Hottest Workplaces — Sukoon, n.d.).

Collectively, these solutions demonstrate a rapidly advancing technological capability addressing different aspects of heat. However, their pathway from pilots to public deployment remain constrained. Almost every innovative product here depends upon an institutional buyer (municipal corporations for heat intelligence, state departments for cooling shelters, labour welfare boards for worker protection) these technologies yet do not fit either in within the existing budget head under which a city or state can purchase heat adaptation technology or in any of the procurement category. Consequently, they are bought through one-off pilot funding through philanthropies or CSR budgets, neither of which supports the multi-year commitment that these products require (Dasgupta et al., 2025).

These technologies are validated on technical performance like sensor accuracy, thermal resolution, energy consumption, degrees of cooling delivered etc. but not on health outcomes. There is comparatively no to little evidence on whether these innovations demonstrated a measurable reduction in HRI presentation or mortality at population scale. That absence of evidence matters, as public buyers need outcome evidence to justify recurring expenditure, and without it there is no basis on which to choose between competing solutions. The result is a hollow layer that is technically strong and well capitalised at the seed stage, but structurally unable to reach the scale its intended buyers would need.

4.1.5 Financing and Insurance

The financing and insurance layer represents one of the most significant structural innovations of the last three years. An informal worker who stops work during a heatwave loses a day's earnings with no mechanism to recover them, and conventional indemnity insurance becomes unusable here: it requires proof of loss, medical documentation, and a claims' process that workers without records or spare time cannot navigate. Parametric insurance removes that barrier by paying automatically when a weather threshold is crossed, with no claim filed and no loss proven (McLeod & Goering, 2025; Saad et al., 2025).

The flagship example is SEWA's parametric heat and rainfall insurance for informal working women. Launched in 2023 across 22 districts of Gujarat as part of a global extreme heat income insurance programme funded by the Adrienne Arsht-Rockefeller Foundation Resilience Center and subsequently scaled from 2024 with Climate Resilience for All, it is underwritten domestically by ICICI Lombard, with Swiss Re reinsuring the tail risk of a heavy claim year. In the insurance scheme, the premium is deliberately blended: members pay roughly a third of it whereas philanthropic capital covers the remainder, with payouts triggered at region-specific thresholds (for example in Ahmedabad, at 43.6°C and again at 44.1°C sustained over two consecutive days). (SEWA's Journey towards Climate Resilience, 2026)

However, one key challenge observed in the initial year itself was that the thresholds were set so high that members received nothing on days that were in practice unworkable, and the trigger had to be recalibrated downward. In a parametric product the threshold is the product and setting it wrong is indistinguishable from having no cover at all. (Parametric Insurance for Extreme Heat: Setting Right Expectations, n.d.)

Another factor is that majority of the premium is covered through philanthropic capital, which is not the design or distribution cost, which would be a normal launch expense, but the annual recurring cost of keeping cover in force. This is a subsidy rather than a market, and it is renewed each year at a funder's discretion. Two routes lead out of it. The first is member-paid premiums, and SEWA's own consultations indicate willingness to pay, but willingness at a subsidised price is not evidence of affordability at the full one, and no scheme has yet tested it. The second is for government to become the premium payer, which is precisely the structure that made crop insurance viable at national scale, where central and state governments carry the bulk of the farmer's premium. No equivalent instrument exists for heat. Until one does, these schemes will remain what they are today: well-designed, actuarially sound, and dependent on donors renewing them every summer.

4.2 What is needed from the Ecosystem

An effective heat adaptation ecosystem must function as a continuous cycle (Figure 4.2).

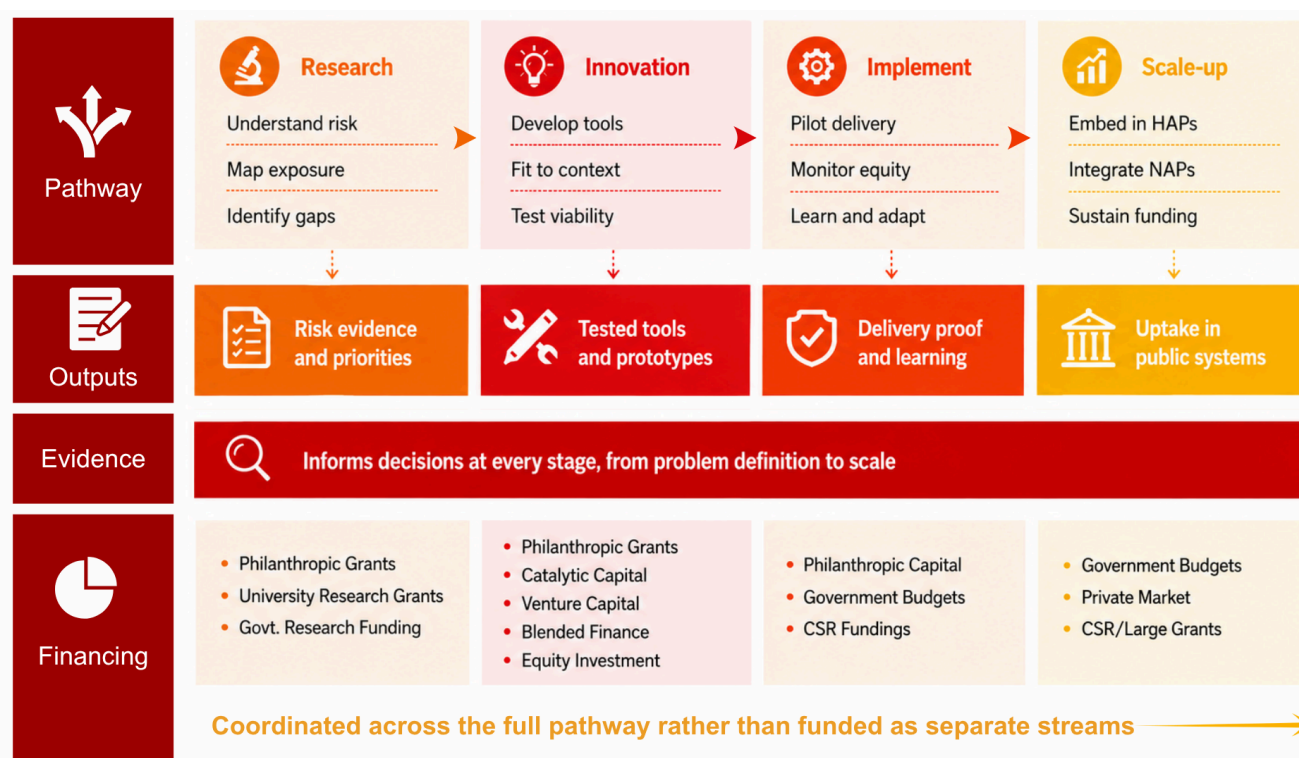


Figure 4.2: Representation of Effective Functioning of Health and Health Adaptation Ecosystem (Source: India Health Fund)

Investments should begin with strengthening the research base to better understand heat-health impacts, identify vulnerable populations, and generate the evidence required to inform interventions. This evidence should then be used to identify critical adaptation gaps and opportunities where innovative solutions can be developed.

Once promising solutions are identified, the ecosystem must support the development and testing of innovations through pilot implementation. Early implementation efforts should be accompanied by robust monitoring, evaluation, and learning frameworks to assess effectiveness, equity, feasibility, and scalability. The evidence generated through these pilots can then inform policy decisions and support the integration of successful interventions into public systems, programmes, and planning processes such as Heat Action Plans and National Adaptation Plans (NAPs).

It is important to note that evidence is not a discrete phase in this cycle but a cross-cutting function: it should inform decisions at every stage from identifying the challenges to understanding the implementation science of innovative heat adaptation solutions for scaling.

Financing has to follow the similar pathway; Research, innovation, implementation, and scale-up are currently funded as separate streams under the very distinct mandates of funders, which is why promising solutions stall between proof-of-concept and public delivery. Closer coordination among funders, governments, research institutions, implementing organisations, innovators, and policy actors would align investment across the full pathway and give proven solutions adequate resources and an established route to integration into the public systems.

4.3 What Does an Integrated Heat Adaptation Solution Look Like?

Heat adaptation requires interventions that cut across sectors, institutions, and service delivery pathways. Therefore, the objective should not be only to support individual adaptation solutions, but also to enable their deployment in ways that enhance the resilience of entire systems.

By combining innovations across the continuum of prediction, prevention, service delivery, and monitoring, it is possible to strengthen the capacity of public systems to respond to both current and future heat risks. A useful way to organise this continuum is by integrating innovative solutions at every step: prediction (forecasting and digital heat intelligence), prevention (cooling shelter, protective garments, and advisories), service delivery (screening, diagnostics, and treatment at heatwave hotspots), and monitoring (tracking heat related adverse outcomes and feeding them back into planning).

As discussed in chapter II - Heat and Health, two of the most significant health impacts of extreme heat in India are the worsening burden of non-communicable diseases (NCDs) and adverse health outcomes for pregnant women. These are particularly severe among vulnerable populations with limited access to healthcare and social protection. An integrated adaptation approach can therefore prioritise strengthening health systems around these high-risk pathways.

One example of an integrated approach is the development of a heat-resilient health service delivery model that combines early warning systems, community-based screening, last-mile diagnostics, and continuity of care mechanisms.

The value of an integrated model lies in demonstrating how innovations originating from different domains can be assembled into coherent adaptation pathways. Such a holistic approach moves beyond isolated pilots and create the foundation for scalable, equitable, and evidence-based heat adaptation embedded within existing health systems.

HEAT-RESILIENT NCD CARE PATHWAY



Heat-Resilient NCD Care Pathway focuses on reducing heat-related morbidity among populations living with NCDs. This approach transforms heat forecasts from a passive warning mechanism into an actionable public health tool that enables proactive identification and management of vulnerable populations.

Early Warning Systems (EWS) and Predictive Modelling:



Climate and health datasets can be integrated to identify emerging heat hotspots, vulnerable geographies, and at-risk populations before extreme heat events occur.

Targeted NCD Screening:

Community health workers can use innovative, minimally invasive diagnostic tools to conduct NCD screening in identified hotspots, enabling early detection of high-risk individuals.



Linkage to Essential Healthcare Services:

Individuals identified as vulnerable can be connected to appropriate health services for diagnosis, treatment, medication adherence, and follow-up care.



Reduced Heat Burden:

Alongside healthcare interventions, adaptation measures such as access to cooling, behavioural risk communication, and heat-risk management can reduce exposure, potentially lowering heat-related cardiovascular and respiratory complications.



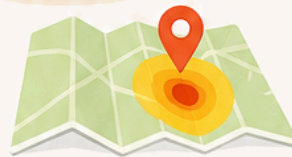
PROTECTING MATERNAL HEALTH DURING HEATWAVES



Protecting Maternal Health During Heatwaves addresses disruptions in maternal healthcare services during periods of extreme heat.

Predicting ANC Service Disruptions:

Early warning systems can be combined with health service utilization data to identify regions where antenatal care (ANC) attendance may decline during heatwaves.



Deployment of Community-Based ANC drives:

Portable diagnostic kits can enable Accredited Social Health Activists (ASHAs) and frontline workers to continue essential maternal health assessments through home-based service delivery when facility visits become difficult.



Structured Home Visit Protocols:

Standardized ASHA-led home visit protocols can ensure continuity of maternal and newborn care, including risk identification, counselling, referral, and follow-up.



Continuity of Essential Services:

Maintaining access to antenatal care during extreme heat events can help reduce the risk of delayed care-seeking, pregnancy complications, adverse birth outcomes, and heat-related maternal and neonatal health impacts.





CHAPTER V

Heat-Health Adaptation Challenges and Innovation Exemplars



Chapter V: Heat-Health Adaptation Challenges and Innovation Exemplars

The challenge in heat-health adaptation is to close critical gaps between what is technically possible, what can be implemented at scale, and what can be demonstrated to deliver measurable health protection against extreme heat. Innovation can help solve these challenges by translating emerging technologies, new delivery models, and locally relevant approaches into practical solutions that strengthen the effectiveness, reach, and scalability of heat-health adaptation. This chapter examines four domains where these gaps are particularly pronounced and showcases innovation exemplars that can help address them: Cooling Solutions, Digital Intelligence, Health System Strengthening, and Behavioural Solutions.

5.1 Cooling Solutions: Closing the gap between exposure and protection

At its most fundamental level, protection from extreme heat is a physiological challenge: when environmental heat gain exceeds the body's capacity to dissipate heat, core temperature rises and the risk of heat-related illness increases. Yet for many of those vulnerable to heat exposure, including outdoor workers, informal-sector workers, older adults, and populations living in poorly ventilated or heat-retaining housing, access to effective cooling solutions remains limited (Castro & Delina, 2025; O'Donnell & Sovacool, 2026; Scheelbeek et al., 2021).

The challenge is translation gap between promising technologies and population-level protection. Personal cooling technologies for heat-exposed workers, rapid cooling devices for pre-hospital and field settings, cool roofs and other passive cooling measures for health facilities and vulnerable housing, and nature-based and urban cooling interventions all offer potential pathways to reduce heat exposure (Lugten & Hariharan, 2022a; WHO Guidance for Climate Resilient and Environmentally Sustainable Health Care Facilities, n.d.).

Among these opportunities, occupational heat exposure represents a particularly immediate and tractable entry point for innovation. Workers in construction, agriculture, transport, waste management, street vending, and other outdoor or high-heat occupations often experience prolonged and predictable exposure, while their ability to modify working environments is limited. (Ioannou et al., 2022; Tamim et al., 2025) The population at risk is relatively identifiable, exposure can be characterised, and interventions can be targeted to specific periods and occupational contexts.

Personal cooling technologies including cooling vests, neck and head cooling devices, phase-change materials, and other wearable approaches are therefore an emerging area of innovation. The central challenge is no longer simply whether such technologies can cool the body, but whether they can deliver meaningful reductions in physiological heat strain under real-world working conditions at a cost and level of usability that enables adoption. Building this evidence base will be critical to determining which cooling solutions warrant public, philanthropic, or market-based investment and where they can deliver the greatest protection per unit of investment.



Eztia: Scaling Passive Cooling for resilience to Extreme Heat

As global temperatures shatter records, the "cooling gap" the disparity between those who have access to air conditioning and those who do not threatens billions of lives. Eztia, a US-based material science startup, addresses this through a proprietary, passive cooling material. By integrating hydrogel technology directly into wearable garments, Eztia provides a power-free solution for heat adaptation, specifically targeting outdoor workers, vulnerable populations, and regions with limited energy infrastructure.



Founding Insight:
Novel technology should be accessible to all and used as medium for equality.

The Genesis

Eztia was founded on the principle that novel technology must serve as a medium for equality, protecting those whose livelihoods depend on enduring the elements. The inspiration for Eztia emerged from founder Tiffany Yeh's decade-long experience in the international development sector. Working in infrastructurally challenged regions—where electricity was unreliable and running water scarce—Yeh witnessed firsthand the lethal intersection of extreme heat and poverty. Recognizing that "active" cooling (AC and fans) is often inaccessible to those who need it most.

Technical Innovation: The Hydrogel "Print"

Eztia's USP lies in its specialized hydrogel

formulation and its application methods. The garments (shirts, arm sleeves, and neck wraps) feature a pattern of printed hydrogel dots. These dots are dry to the touch but saturated with water. When worn, the dots absorb body heat through conduction and dissipate it via evaporative cooling. The "Recharge" Cycle: Unlike phase-change materials that require refrigeration, Eztia's textile is recharged simply by washing it or soaking it in water. Design Evolution: The product underwent several iterations based on user feedback:

- 1. Phase 1 (The Patch):** Highly modular but cumbersome for daily use.
- 2. Phase 2 (The Pocket Shirt):** Integrated hydrogel into pockets; however, users found the weight prohibitive.
- 3. Phase 3 (The Printed Dot):** The current design prints small dots directly onto breathable fabric. This maximizes freedom of movement and optimizes heat dissipation.

Adapting to Humidity vs. Aridity

- **Hot & Humid (e.g., Singapore):** Small, distributed dots allow for consistent cooling without over-saturating the wearer's microclimate.
- **Hot & Dry (e.g., Middle East):** In arid air, water evaporates faster. Eztia can adapt by printing larger dots with higher gel volume, ensuring the cooling effect lasts throughout an entire work shift despite the accelerated evaporation rate.

Impact and Performance

In high-temperature, high-humidity environments, Eztia's garments reliably reduce skin temperature by 5°C (and up to 10°C in controlled settings). Due to small batch manufacturing, the costs are on a higher side (Sleeves: \$37; Shirts: \$57) but with economies of scale the product will be accessible to masses at significantly lower cost.

Currently, Eztia operates on a B2B and B2G (Business-to-Government) model. This strategy targets the following groups:

- 1. Occupational Safety:** Logistics, construction, shipping, and prison officers.
- 2. Public Sector:** School children (Physical Education), elderly care, and local government personnel.

Geographic Footprint: Current operations are centered in Singapore, Japan, and the United States with intentions to expand to South and Southeast Asia and Middle East.

Stakeholder Engagement and Public Partnerships

Eztia's expansion strategy relies heavily on deep integration with local governance. A standout example of this collaboration occurred in Hokkaido, Japan, where the local government and the Ministry of Education joined forces to distribute Eztia's cooling headbands to students. Eztia found that engagement is most effective when:

- **Deep Community Ties Exist:** Governments that are intimately familiar with their citizens' specific needs can deploy technology more effectively.
- **Internal Champions:** Successful adoption requires "innovation promoters" within the government, individuals who advocate for new solutions to solve problems.

User Spotlight: Field Insights

The true value of the technology is best articulated by those on the front lines of heat exposure. An Officer from the Singapore Prison Service shared: "Overall, the product does make the body feel cooler even if the [sudden] feeling is not there. The cooling effect is amplified when you are wearing it in an air-conditioned environment. This means that after doing operations for a while, when you rest in the office, you feel even cooler than when you were outside in the Correctional Unit. Even when the cooling dots are not in perfect condition, they still absorb and retain moisture, maintaining the garment's effectiveness."

Global Replication: Barriers and Requirements

While the need for passive cooling is universal, replicating Eztia's success in new geographies like India presents unique challenges. Founder Tiffany Yeh identifies geographic unfamiliarity as a significant operational barrier. To overcome this, the company seeks strong local partnerships to provide the necessary cultural and logistical intelligence to navigate new markets.

The Way Forward: Scale and Circularity

Eztia is currently transitioning from pilot projects to full enterprise-scale operations. Their roadmap focuses on three pillars:

- **Market Expansion & Affordability:** By simultaneously expanding manufacturing and market reach in South/Southeast Asia and the Middle East, Eztia aims to leverage economies of scale to bring unit costs down, making the product accessible to the masses.

- **Sustainability & R&D:** In collaboration with Nanyang Technological University (NTU) and the Temasek Foundation, Eztia is researching the product's "End-of-Life" management, developing methods to dissolve or recycle the hydrogel and exploring ways to upcycle materials to ensure a circular product lifecycle. Eztia is also working with specialized research labs to measure physiological data to better serve highly vulnerable populations, specifically elderly population in care homes, where heat regulation is a critical health factor.

- **Customer Experience:** Eztia is developing an innovative communication strategy focused on user education, ensuring that those in the most remote or heat-affected areas understand how to maximize the garment's cooling potential.



Lashing specialist at PSA Singapore trialing Eztia arm sleeves, torso wrap and bandana. October 2025

5.2 Digital Intelligence: Closing the Data Gap in Heat Risk and Response

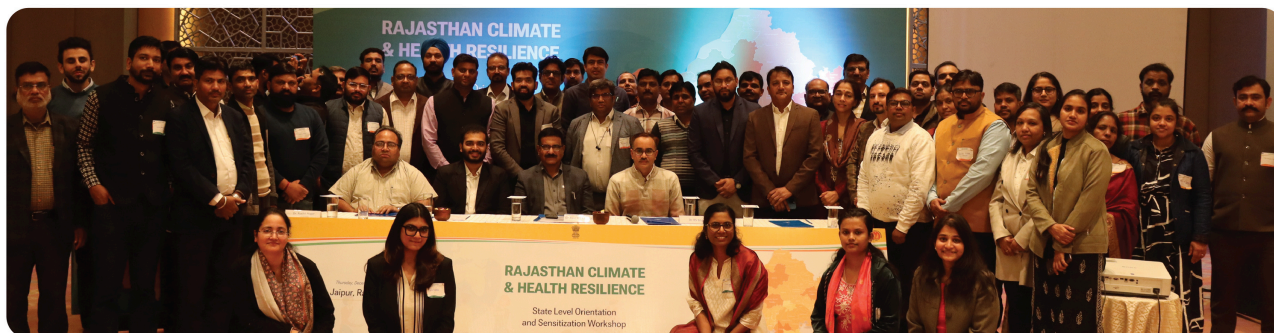
Across the heat-risk continuum, relevant information exists across meteorological, health, demographic, environmental, and administrative systems, but these data streams rarely connect in ways that enable decision-makers to anticipate risk, target interventions, and respond in real time. The critical gap is therefore a data-to-decision intelligence.

1. Current early warning systems rely largely on meteorological thresholds that do not fully account for differences in local vulnerability, exposure, physiological susceptibility, and adaptive capacity. Moving from temperature-based warnings towards impact-based and vulnerability-informed intelligence is therefore critical to making alerts more locally relevant and actionable (Bhawra et al., 2025; Dasgupta et al., 2025).
2. Interoperability between climate information systems and health information systems is weak to non-existent: heat alerts generated by meteorological agencies do not automatically trigger health system responses, and health data on HRI presentations does not automatically flow back meteorological agencies to calibrate alert thresholds (Bhawra et al., 2025)
3. Heat-health surveillance remains fragmented. Heat-related deaths are likely to be under-recognised or misclassified, while HRI is often not systematically distinguished from broader emergency or outpatient presentations. More importantly, upstream indicators of rising heat stress such as changes in emergency visits, ambulance calls, occupational exposure, or other real-time signals are rarely integrated into a common intelligence layer that can trigger early intervention before severe outcomes occur (Bhawra et al., 2025; Dasgupta et al., 2025; de Bont et al., 2024).
4. Heat also disrupts access to essential health services when demand for health protection may increase. During periods of extreme heat, travel can itself become a health risk, particularly for older adults, pregnant women, people with chronic conditions, and those living or working in high-exposure environments. While telemedicine and other remote-care models could help maintain continuity of care for routine services such as antenatal care, NCD management,

primary care during peak heat periods, its effectiveness as a heat-adaptation measure, including the ability to reach the populations most at risk, remains insufficiently evaluated (Saad et al., 2025).

Innovation can help address some of these gaps by developing interoperable platforms that use predictive analytics, AI-enabled risk stratification, digital surveillance tools, and decision-support systems that convert existing data into actionable intelligence without requiring every component of the system to be rebuilt from scratch.

Real-time signals from existing systems, when intelligently connected, interpreted, and translated into predefined actions, can support better protective decisions today while stronger evidence is generated in parallel. The innovation opportunity is therefore to build the intelligence layer that connects data to decisions, and decisions to timely health protection.



Climate and Health Vulnerability Index: Closing the Climate-Health gap by turning data into last mile action

As climate change intensifies, its effects are increasingly manifesting as public health emergencies. Yet, there is a lack of localized, real-time systems to identify who is most at risk, where vulnerabilities are concentrated, and how to respond proactively.

Khushi Baby, a public health non-profit organization, addresses this challenge through an AI-based decision support framework called 'Climate and Health Vulnerability Index (CHVI)' that helps assess climate-related health risks and enable proactive public health interventions to reduce community health risks.



Founding Insight:

The tool enables Khushi Baby to work with governments to uncover hidden heat-health vulnerabilities, prioritize who and where to act, and turn data into targeted actions while continuously tracking their real-world impact. This requires a fundamental shift: from reactive health systems that respond only after hotspots emerge or outbreaks occur, to anticipatory ones built to predict risk, prevent harm, and protect the most vulnerable before a crisis hits. Khushi Baby's thesis is captured in a simple sequence:

Predict > Prevent > Protect Vulnerable Communities.

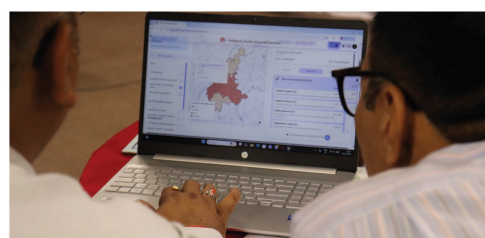
The Genesis:

Khushi Baby's work on climate and health emerged during and after the COVID-19 pandemic, when the organization began reflecting on the broader applicability of the community health data systems it had built over nearly a decade in the state of Rajasthan in India. They recognized a fundamental gap in climate adaptation i.e. climate data and vulnerabilities sit separately from health data and vulnerabilities, and there is no consistent intersection between the two.

The team found that these silos often produced

misleading assumptions. For example, in Rajasthan, districts like Jaisalmer are widely perceived as the most vulnerable because they experience the highest temperatures. However, once climate indicators were integrated with health conditions, occupational exposure, adaptive capacity, and population density, districts such as Rajsamand emerged as significantly more vulnerable from a climate-health perspective. This insight became foundational to Khushi Baby's approach: climate exposure alone does not determine vulnerability.

Khushi Baby initially developed the Climate and Health Vulnerability Index as a prototype and submitted it to the MIT Solve Challenge, where it was recognized as a winning solution for health in fragile contexts. The recognition provided seed funding to further refine the model and establish a dedicated climate-health team within the organization.



Technical Innovation:

Khushi Baby's Climate and Health Vulnerability Index is a framework designed to turn climate risks into actionable health insights. It is a first-of-a-kind public health decision-support tool that brings together climate exposure, population sensitivity, and adaptive capacity to identify climate-health risks across district and sub-district levels. Khushi Baby's key innovation lies not merely in collecting data, but in integrating datasets that traditionally exist in isolation and converting them into operational insights for public health officials. The CHVI leverages the foundation of the Community Health Integrated Platform (CHIP), integrating village-level health data from CHIP and other sources such as the National Non

Communicable Disease Portal, Maternal and Child Health Portal, and climate data from sources like the India Meteorological Department (IMD), Remote Sensing Data from European Space Agency and Google Earth Engine Co-designed by local health officials, CHVI will be designed for use at the block, and district levels, combining granular data from climate, health, and socio-demographic sources. The index generates a comprehensive vulnerability score by analyzing three key dimensions: exposure (e.g., heat, air quality), sensitivity (e.g., health status, population demographics), and adaptive capacity (e.g., healthcare access, socioeconomic resilience).

The CHVI integrates four major dimensions, namely: Climate Exposure, Health Sensitivity, Socioeconomic and Built Environment Vulnerability Health System Adaptive Capacity

Building on its existing Community Health Integrated Platform (CHIP), which serves 60 million beneficiaries through 85,000+ health workers and integrates 40+ government systems, Khushi Baby developed CHVI to convert climate and health data into action. Operating across communities, frontline workers, and health systems, CHVI enables real-time forecasting and targeted responses for at-risk populations.

Objective:

Overall, it aims to integrate climate & health vulnerabilities, deliver granular insights with high accuracy, use real-time data & machine learning for forecasting, enable proactive responses for at-risk communities.

Impact and Performance:

Khushi Baby in collaboration with the Government of Rajasthan completed a statewide Heat Health Vulnerability Workshop across all the districts, meaning 40+ districts across Rajasthan can now identify and prioritize vulnerable households before extreme heat shocks hit. Separately, the state has made a formal commitment to validate and integrate CHVI into climate-health planning, issued a mandate to build capacity across health decision makers at district and sub-district levels and integrate its learnings into Jaipur Heat Action Plan in collaboration with other developmental partners.

Khushi Baby is undertaking active initiatives in expanding across domains beyond heat, including vector-borne disease and air pollution to reach for the last-mile impact.

Stakeholder Engagement and Public Partnerships:

Khushi Baby has extensively engaged with the

government officials in the state of Rajasthan. Rather than operating parallel systems, Khushi Baby embeds itself within government workflows and decision-making structures. Government engagement has shaped the platform iteratively. Due to the nature of its innovation, Khushi Baby has actively engaged and build partnerships to support primary users of the platform, like officials from district and state health departments, block-level administrators, climate nodal officers and district collectors and cross-sectoral planners.



User Spotlight: Field Insights:

District officials used the HHVI dashboards during workshops held in March 2026 to identify the most vulnerable blocks and populations. The analysis highlighted outdoor workers particularly mining and stone workers as a highly vulnerable group that is often excluded from formal planning and response efforts. Based on these insights, officials documented a plan with targeted interventions including organizing health camps near work sites, training ambulance service providers on the heightened risks faced by outdoor workers and conducting awareness activities in areas with high worker density.

Barriers and Challenges:

A key challenge for Khushi Baby was integrating datasets at different levels of granularity (example: satellite-based climate data and health data available at block, PHC, or Anganwadi levels). To make these datasets interoperable, Khushi Baby standardized them to common geographies, initially at the block level where many health decisions are made.

The Way Forward: Scale and Circularity:

Khushi Baby's goal is to create an operating system, which will support more granular and targeted climate-health decision making by the government officials and deploy solutions to reach towards the last-mile impact. The long-term vision is national-level replication through policy adoption, contributing to India's national climate-health strategy and the global evidence base. Based on the current technical model, the way ahead for Khushi Baby lies in strengthening the model and data-driven government operational flows that can best be suited for use in prioritizing transformation from a data and dashboard to action.

The screenshot shows the Climateverse interface for a dataset titled "IMD Total Number of Disastrous Heat Wave Days". At the top, the Climateverse logo is on the left, and navigation links (Search, User Guide, Support, Sign Up, Log In) are on the right. The dataset title is prominently displayed. Below it, a version tag "Version 1.0" is shown. A document icon is next to the dataset description: "India Meteorological Department, 2025, 'IMD Total Number of Disastrous Heat Wave Days', [https://doi.org/10.71646/K9ZHZZ](\"https://doi.org/10.71646/K9ZHZZ\"), Climateverse India, V1". Action buttons include "Show Dataset", "Cite Dataset", "Contact Owner", and "Share". A "Dataset Metrics" box shows "0 Downloads". Below this, a section titled "Climate Hazard and Vulnerability Atlas of India - Heat Wave Days" features a map of India, icons for "Dataset Source: Records And Monitoring", "Frequency: Yearly", "Availability: Open Access", and "File Format: Dashboard". To the right, "Other Data Metrics" are listed: Range (1989 - 2019), Spatial Aggregation (District), Documentation Availability (Metadata and Codebook), Data Provider (India Meteorological Department), and Data Updated status (indicated by a red 'x'). A "Description" section at the bottom explains that the dataset is the "Total Number of Disastrous Heat Wave Days (Annual)" from the IMD Hazard Atlas website, covering the period 1969 to 2019.

Climateverse: Advancing Data Literacy for Climate Action

At a time when climate vulnerability data is exploding across sectors and geographies, the real challenge is no longer the absence of information, but the inability to discover, interpret, and apply it meaningfully. Climateverse emerged from this precise friction point: while governments, research institutions, NGOs, and private platforms were producing enormous quantities of climate-related datasets, stakeholders on the ground struggled to answer a deceptively simple question—Which data should we trust, and how do we use it?



Founding Insight:

Dr. Satchit Balsari, Associate Professor in Emergency Medicine, Harvard Medical School and Beth Israel Deaconess Medical Center
 “Climateverse is a searchable, open-source repository of curated datasets annotated with a range of metadata describing the provenance, accessibility, availability, accuracy, timeliness and cost of data, among over 60 other categories. LLMs and Generative AI ease exploration. Climateverse fills an urgent research need - it points to verified sources of climate and health data, and provides reliable descriptions of quality, usability and limitations”.

User Insight:

Dr. Farzana Misha, Associate Professor, BRAC University
 “Bangladesh is on the frontlines of the global climate

crisis. While a vast amount of climate and environmental data exists within the country, it remains highly fragmented across various organizations. Climateverse bridges this gap by bringing all of these isolated datasets into a single, unified platform, making it accessible for people to find and utilize the data they need”.

The Genesis:

Understanding the Data Architecture Crisis

The origins of Climateverse lie in the lived operational challenges faced by its founding members themselves in attempting to triangulate datasets across vulnerability indicators, infrastructure layers, meteorological records, demographic repositories, and local governance databases, the team encountered a fragmented and often incoherent data ecosystem. Different institutions maintained different versions of datasets, metadata was incomplete or inconsistent, and there was no standardized way to assess the usability or reliability of information for downstream applications. Rather than attempting the near-impossible task of consolidating all climate datasets into a single repository, Climateverse pursued a more strategic question: Could the discoverability and interpretability of climate data itself be standardized?

To understand the scale of the problem, the Climateverse team convened over 100 stakeholders across the climate and disaster-response ecosystem.

Their inquiry centered on: How does one assess the quality and usability of climate data? What emerged from these consultations was a recurring pattern across sectors and institutions:

- i. Stakeholders often spent more time searching for usable datasets than conducting analysis.
- ii. Metadata was frequently patchy, missing, or incompatible across repositories.
- iii. Multiple portals hosted similar datasets (temperature records, rainfall data, demographic layers) but there was no “gold standard” framework to evaluate which source was most appropriate.
- iv. Existing climate dashboards focused heavily on visualization through maps and graphs, but rarely answered operational questions such as: Is this dataset updated? What are the limitations of this data source? What critical variables are missing? Can this dataset be trusted for policy or emergency response?

The result was what the Climateverse team described as a growing “**data graveyard**”: large quantities of publicly available data that remained effectively unusable because stakeholders couldn’t understand applicability, quality, and context. As one member of the Climateverse team reflected: “A lot that goes wrong in data science is not the data, but the question you are asking and the process.” This realization shaped the foundational philosophy of Climateverse: transparency about what is known, what is uncertain, and what data gaps still exist is often more valuable than presenting incomplete answers with false confidence.

Technical Innovation

The platform operates through three interconnected layers:

1. Dataset Architecture

Climateverse developed a standardized metadata framework and identified six thematic domains with 36 metadata parameters to evaluate datasets consistently. The system began as a simple spreadsheet mapping exercise, where datasets were tagged against these parameters. Over time, this evolved into a sophisticated backend schema architecture integrating both standard Harvard Dataverse metadata structures and Climateverse-specific extensions (“Dataverse+”). The framework was intentionally developed through bottom-up expert consultation rather than imposed as a top-down standard, ensuring usability across sectors and geographies.

2. Metadata Smart Cards

Every dataset on Climateverse is accompanied by an automatically generated “smart card” summarizing

key metadata characteristics, including source credibility, update frequency, missing parameters, accessibility constraints, geographic and thematic relevance and interoperability with other datasets etc. Whenever a dataset is updated, the connected GitHub repository automatically refreshes the smart card and synchronizes it with the Climateverse frontend. Rather than claiming to provide definitive answers, Climateverse surfaces a transparent assessment of what the available evidence can and cannot support.

3. AI Engine

Climateverse also integrates a proprietary AI engine designed specifically for climateverse. Unlike generalized AI systems, the platform’s AI infrastructure is intentionally self-hosted rather than dependent on commercial large-language-model platforms such as ChatGPT or Claude. This design decision was driven by the need for: response consistency, domain-specific guardrails, precision in dataset interpretation and controlled validation processes. The AI layer is designed not merely to retrieve datasets, but to guide users through the interpretive process of identifying relevant datasets, explaining relationships between datasets, highlighting uncertainties, and surfacing critical data gaps that require further evidence generation.

From Research Tool to Policy Infrastructure

Climateverse was designed for multiple user groups rather than a single technical audience.

1. Research Applications

For researchers, the platform functions as an early-stage discovery and hypothesis-generation tool. It enables users to map existing evidence landscapes, identify data limitations, formulate research questions, and understand how datasets interact across domains.

2. Policy and Emergency Response Applications

Climateverse is also being positioned as a tool for policy officers and climate emergency management agencies navigating increasingly data-intensive adaptation planning. An early example emerged from Kerala, where stakeholders reported that Climateverse accelerated the initial discovery and coordination processes required for developing data-driven hazard and risk mitigation strategies. The platform’s collaborative architecture also helps solve one of the most persistent barriers in climate governance: interdepartmental coordination. These engagements focused not simply on technology deployment, but on integrating Climateverse into institutional coordination processes: An area the team identifies as one of the hardest operational

challenges in climate governance. This embeds climateverse directly into coordination workflows rather than functioning as a standalone data portal.

3. Data Governance and Privacy by Design

One of Climateverse's distinguishing features is its compatibility with evolving data protection regulations. Using climateverse permission structures, organizations can configure tiered access systems. For example, organizations can allow only users with approved institutional email domains to access sensitive datasets. This architecture allows institutions to maintain control over their own data infrastructure while still participating in broader climate-data ecosystems. The result is what can be described as a "verse within a verse": organizations can host customized climate dataverse tailored to specific operational needs while remaining interoperable with wider public datasets. Climateverse enables these datasets to interact with public-sector information such as meteorological and health department datasets, allowing stakeholders to develop a more integrated understanding of climate risk.

Cross-Border Applications and Global Expansion

Climateverse is currently operating across India, Bangladesh, and Mexico through a deliberately phased expansion strategy centered on local institutional partnerships.

Persistent Challenges

Despite its progress, Climateverse continues to confront structural limitations inherent to the climate-data ecosystem itself.

1. Data Validation and Link Rot:

Climate datasets evolve constantly. Links expire, repositories merge, and metadata structures change over time. In one recent validation exercise climateverse team found, more than 20 dataset links had become inaccessible or outdated, requiring manual verification and correction. To address this, Climateverse is exploring AI-assisted authenticity and link-validation system.

2. Missing and Inaccessible Data:

Many critical datasets remain unpublished, institutionally siloed, or locked in inaccessible formats. Recognizing that Climateverse alone cannot solve this systemic issue, the team is exploring publication of a "State of the Climate Data Landscape" assessment to identify persistent evidence gaps and guide broader ecosystem to work on some of these challenges of addressing the missing data gaps.

The Vision: Interoperable Climate Collaboration

Climateverse's long-term vision extends beyond metadata management. The platform envisions a future where: one organization hosts air pollution and lung health data another hosts heat-health vulnerability data, and both can securely collaborate to examine how heat and air pollution jointly affect health outcomes. In this model, Climateverse becomes not simply a discovery tool, but a collaborative infrastructure layer enabling institutions to work across sectors, datasets, and geographies to generate integrated climate solutions. At its core, Climateverse reframes climate adaptation not as a problem of data scarcity, but as a challenge of data literacy, interoperability, and institutional coordination.

5.3 Health System Strengthening: Building a Heat-Ready Care Delivery System

The dominant model of heat-health response in India remains largely facility-based: patients who reach health facilities during a heatwave receive care; those who do not may remain outside the system (Saad et al., 2025). This approach is poorly suited to a hazard where timely intervention can determine whether heat stress deteriorates to severe illness. Outdoor workers who develop symptoms at worksites, older adults living alone, and residents of heat-vulnerable communities located far from healthcare facilities may be among those least able to access care when risk is highest. A heat-ready health system must therefore extend beyond the facility to anticipate risk, identify vulnerable populations, and deliver prevention, early detection, and care closer to where exposure occurs.

Health facilities and the health workforce face a dual burden during extreme heat: an increase in acute heat-related illness coincides with additional presentations and complications from chronic conditions that are exacerbated by heat. At the same time, diagnostic and monitoring capabilities needed for timely detection and management such as heat stable point-of-care tools for NCD monitoring, antenatal assessments, remain unevenly available, particularly at primary and community-level (Bassey et al., 2025; Gkouliaveras et al., 2025; Mishra et al., 2025; Saad et al., 2025). These gaps can contribute to delayed diagnosis, inappropriate triage, and avoidable escalation to higher levels of care.

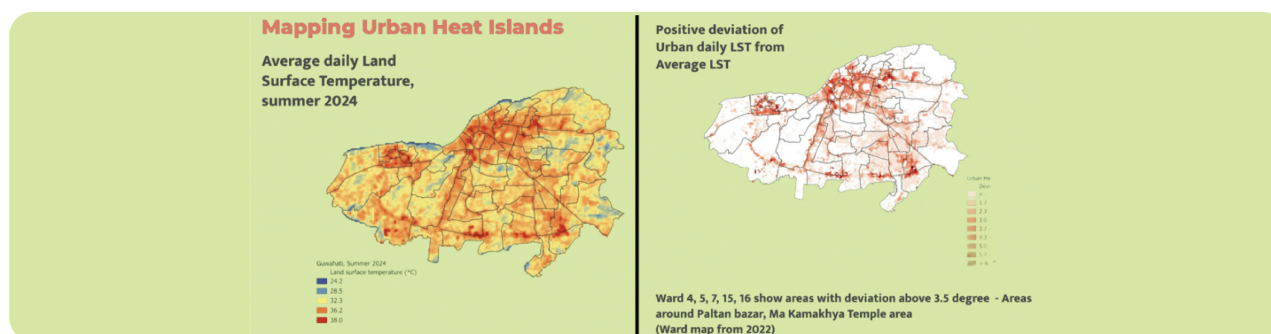
A heat-ready system must also ensure the basic necessities required for care and prevention are available and accessible to all. For instance, access to safe drinking water is a foundational component of heat-health protection, yet heatwaves can coincide with water shortages and other disruptions that undermine access when demand is highest. Health facilities and vulnerable communities therefore require resilient WASH infrastructure as part of heat-health preparedness (Bassey et al., 2025; Lugten & Hariharan, 2022a, 2022b; March et al., 2026; Mishra et al., 2025; Saad et al., 2025).

Heat also creates important decision-making challenges outside the health sector. Two potentially important economic protection mechanisms; i) adjustments to working hours

and ii) heat-linked parametric insurance or other financial protection mechanisms for exposed workers should be based on reliable, locally relevant information about heat exposure. Where decisions rely primarily on broad meteorological thresholds, they may fail to reflect the microclimatic conditions experienced by workers across different occupations and locations. Connecting health, meteorological, occupational, and financial risk intelligence could enable more targeted and timely protective action. However, the ability to make such targeted decisions depends on a stronger understanding of how heat-health exposure interacts with the broader environmental and social conditions that shape health risks (Bhawra et al., 2025).

Another area where limited understanding hinders protective action is extreme heat and air pollution. High temperatures and poor air quality frequently coexist and compound health risks but remains insufficiently integrated into local risk assessment and response systems (The Synergies of Heat Stress and Air Pollution and Its Health Impacts, n.d.-b).

Addressing these evidence gaps is essential not only for improving risk assessment, but also for translating heat intelligence into practical action at the point where people experience exposure. Innovation can help shift heat-health adaptation from a predominantly reactive model towards anticipatory, distributed, and risk-informed care. Opportunities include decentralised diagnostics and monitoring, community-based screening and referral, digital decision-support tools, heat-responsive primary care, resilient water and cooling solutions for health facilities, and integrated systems that connect heat-risk intelligence with frontline health action.



CivicDataLab: Building a Climate & Health Data Collaborative for Heat Resilience

As extreme heat becomes a growing public health threat, fragmented climate and health data continue to limit effective action. CivicDataLab (CDL) is addressing this gap by integrating climate and health intelligence, generating hyperlocal insights, and amplifying community voices to support governments in building evidence-based heat resilience strategies.



Founding Insight:

Gaurav Godhwani, Executive Director and Co-founder, CivicDataLab

"Eastern India is heating up, and we are not paying enough attention. As climate change increasingly impacts health outcomes, the systems that generate and use climate and health data continue to operate in silos. Building a climate and health data collaborative is about bridging these gaps, by enabling local governments, researchers, businesses and vulnerable communities to make better-informed decisions and strengthen resilience where it is needed most."

The Genesis

Founded eight years ago as a research and innovation lab working at the intersection of data, AI, governance, and public good, CDL has spent nearly a decade strengthening evidence-based decision-making across public systems.

CDL began its climate work in 2019 through collaborations with state governments on climate finance adaptation planning, and disaster resilience. Working alongside state governments in states such as Assam and Odisha, CDL identified an opportunity to strengthen the evidence base supporting climate adaptation investments and help policymakers better understand where resources were being deployed and how they could maximize impact on vulnerable communities.

As CDL expanded its work into disaster risk reduction and climate resilience, a recurring challenge became

increasingly visible: climate and health data existed in parallel systems. Recognizing this disconnect, CDL began developing the Climate & Health Data Collaborative, an initiative aimed at bridging climate and health ecosystems through integrated data, evidence generation, and community-centred intelligence.

The objective is to help governments, practitioners, and communities better understand heat-related risks and make more informed decisions around adaptation, preparedness, and resilience. The initiative builds on CDL's broader experience developing data collaboratives, climate resilience platforms, and the Intelligent Data Solution for Disaster Risk Reduction (IDS-DRR), which integrates multiple datasets to support evidence-based planning and decision-making.

Technical Innovation

Simonti Chakraborty, Climate Health Lead, CivicDataLab

"Building a climate and health data collaborative has the potential to strengthen transparency, enable policy dialogue, and create an ecosystem for data-driven decision-making at the most granular levels of governance. By bringing together diverse datasets, institutions, and communities, we can help ensure that climate and health risks are understood and addressed in a more integrated and actionable way."

The Climate and Health Data Collaborative centres on developing a dynamic data-driven heat and health ecosystem that combines data integration, predictive analytics, financing insights and community intelligence. The solution comprises four interconnected components:

1. Climate & Heat Health Data Exchange

An open-source data exchange platform that aggregates climate, meteorological, health, and public service delivery data from government

agencies, research institutions, and civil society organizations. The platform accommodates both open-access and restricted-access datasets while creating standardized formats that improve discoverability and interoperability.

2. Analytics Engine

A risk assessment system that combines climate and health indicators, generates risk assessments at district, sub-district, city, ward and community levels, enabling governments to identify hotspots and prioritize interventions.

For example, preliminary heat-mapping exercises in Guwahati revealed neighbourhood-level variations in land surface temperature, highlighting specific wards experiencing significantly higher heat exposure than the city average. Such analyses help identify priority areas for targeted adaptation and public health interventions.

Analysis of land surface temperature identified neighbourhood-level heat hotspots, with several wards recording temperatures significantly above the city average. Such hyperlocal insights can support targeted heat adaptation measures, public health preparedness, and resource allocation.

3. Citizen Voice and Community Intelligence

A multilingual chatbot designed to capture community experiences during heat events. The tool collects information on health symptoms, work disruptions, stress, anxiety, and other heat-related impacts. The resulting qualitative evidence complements official datasets and strengthens localized decision-making.

4. Heat Health Financing Framework

A budgeting and financing framework that links evidence generation with public finance decisions. The framework helps state disaster management authorities, health departments, and finance departments align investments around heat adaptation priorities and create dedicated heat-health budgets.

Impact and Progress

While the initiative remains in an implementation phase, several foundational components are already operational. The Heat Health Data Exchange is dynamic and evolving rapidly. Data integration systems have been established, stakeholder engagement mechanisms are underway, and community consultation approaches are being piloted through chatbots. Early engagements in Assam have contributed to discussions on incorporating community inputs and heat-health monitoring into planning processes. State authorities are also exploring dedicated budgeting mechanisms for heat preparedness and response.

Stakeholder Engagement and Public Partnerships

Rather than delivering standalone tools, CDL co-designs solutions alongside government stakeholders, ensuring that systems are integrated into existing decision-making processes. CDL works closely with SDMAs, NHMs, CSOs, academic institutions and ULBs.

User Spotlight:

Mrunmayee Velaukar, a public health researcher from PATH & as a user of the platform

"CDL's Climate Health Data Collaborative stands out as a powerful platform not just for insights, but for collaboration and cross-learning. I particularly liked the idea of bringing together diverse stakeholders, enabling shared understanding and collective action on climate and health data across Asia-Pacific. The accessible, well-structured data will help foster meaningful dialogue and informed decision-making across sectors. A truly enabling space for knowledge exchange and community-driven impact."

Barriers and Challenges:

The journey has exposed several systemic barriers:

- **Data Fragmentation:** Climate and health datasets remain siloed across institutions, often collected using incompatible standards and reporting structures
- **Limited Local Capacity:** Many local governments are too overburdened and have limited resources or are limited to perform rigorous analysis and translate climate and health data into operational decisions
- **Limited Data Sharing:** Many government departments are sensitive to share data even when privacy risks are minimal
- **Institutional Fragmentation:** Responsibilities for heat preparedness are frequently distributed across multiple agencies, creating ambiguity and slowing action.
- **Geographic Inequity:** While western India has attracted considerable investment in heat adaptation initiatives, eastern India continues to receive comparatively limited attention despite growing evidence of heat-related impacts.

The Way Forward: Scale and Circularity

CDL's next phase aims to expand the Heat-Health Intelligence Ecosystem to at least six Indian states, including Assam, Odisha, Tamil Nadu, Kerala, Uttar Pradesh, and Bihar, while also strengthening regional partnerships across the Asia-Pacific.

By transforming heat action plans from static documents into living repositories of evidence, CivicDataLab is building the foundations for a more responsive, data-driven, and equitable approach to climate adaptation, placing health outcomes at the centre of resilience planning.

5.4 Behavioural Solutions: Translating Awareness into Action

The protective measures appropriate for a pregnant woman living in a peri-urban settlement differ from those appropriate for an outdoor construction worker, an older person with cardiovascular disease, or a child attending a school during heatwave month. Current information, education and communication (IEC) approaches remain predominantly broadcast-oriented, generic in content, and weakly connected to localised, real-time early warning information. As a result, technically correct advice may reach people without the timeliness, geographic specificity, or population relevance required to translate awareness into protective action.

Advice needs to reflect who is at risk, where they are exposed, when risk is highest, and what action is feasible in that context for that population group. Innovation can strengthen this layer through targeted digital messaging, vernacular and locally relevant communication, behavioural nudges, community-based delivery models, and systems that dynamically link early warnings to population-specific protective guidance. The objective is to move from simply communicating that heat is dangerous to delivering actionable information that enables people to make timely, feasible changes in behaviour.

The health workforce, on the other hand, faces a behavioural preparedness gap. Inadequate and infrequent training on the prevention, recognition, and clinical management of HRIs can translate into delayed identification of severe illness, missed opportunities for early intervention, and incomplete reporting. The challenge is to translate knowledge into consistent clinical behaviours under conditions of heatwave-related surge and pressure. Behavioural preparedness of the health workforce must extend beyond one-time awareness or pre-season training to year-round activity through standardised protocols, practical simulation-based training, and decision-support tools that help embed appropriate practices before and during heat events.

Infrastructure and technology can expand the capacity to protect populations, but they cannot substitute for a person making the right decision at the right time whether that is a worker recognising the need to stop work, a caregiver identifying early symptoms, or a health worker recognising and rapidly treating heat stroke. The innovation opportunity is therefore to strengthen the human interface of heat adaptation: making risk information more relevant and actionable for communities, while equipping frontline health workers with the knowledge, tools, and protocols needed to act on it.



Centring People in Heat–Health Adaptation: The Work of Prayas (Pune)

Framing the Problem: A Multi-disciplinary Approach to Climate and Health

Established in 1994 and based in Pune, Prayas operates through two independent groups: Prayas Energy, which works on energy policy and analysis, and Prayas Health, which addresses a range of public health issues spanning HIV, SRHR, preventive oncology, and Climate change and health. The heat–health initiative is a joint effort of the health and energy group.



Founding insight:

“Extreme heat is a complex challenge. Addressing it requires solutions that fit local contexts, and the active involvement of people in shaping and sustaining them.”

Informed by this perspective, in 2021–22, the work started with a scoping review on India's heat–health literature. It surfaced a critical gap. The evidence base was skewed towards clinical research, mostly looking at city-level mortality risks, while the voices of people themselves were largely absent. Prayas asked a different set of questions: what do people think about heat-related discomfort, how are they coping, and what are the drivers of vulnerability that matter to the community? While most Heat Action Plans acknowledge the need to contextualise interventions, the implementation context is usually missing. The vulnerability is typically assessed through population density, population size, and meteorological data alone. For Prayas, context is also formed by people's economic status, their socio-cultural milieu, how they perceive heat, and how they prioritise it against competing risks.

Research Focus: Understanding the lived experiences of vulnerable communities and the preparedness of the primary health system

Prayas' ongoing research among outdoor workers (street vendors, construction workers, and manual labourers) in Pune city is driven by two converging concerns:

- The near-total absence of these workers' own voices in the heat–health evidence base, despite them being the most exposed.
- Very little evidence on how local context shapes the vulnerability of these communities and their sense-making of heat health risks

A parallel component examines the perceptions and "health preparedness" of primary healthcare workers who form the first point of contact — the medical officer at the urban primary health center, community health workers, and private general practitioners.

The objective is to generate contextual, people-centred evidence on how extreme heat affects vulnerable populations, and to use it to build adaptation solutions that people can actually act upon.

Methodologically, Prayas followed a mixed-method approach, which included qualitative interviews complemented by quantitative data.

The work has produced a conceptual framework spanning macro, meso, and individual-level factors — intersectionality on one side, and urban design, housing, and local governance on the other — that innovators should account for before deploying solutions. The work has been supported by Indian Council of Medical Research and Rohini Nilekani Philanthropies.

Key Insights: Emerging Signals from the Field

Prayas's mixed-method enquiry reveals that heat vulnerability is as much social as it is physiological, and that the populations classified as most vulnerable often do not recognise heat as a health risk at all.

- **Bodily experience over measurement:** They register rising heat through bodily experience and

discomfort rather than degrees.

- **"Humko kuch nai hota hai" (Nothing happens to us):** The people researchers call vulnerable often describe themselves as more resilient. Having worked through high heat stress, they expect to manage further rises in heat stress. This reflects poor risk perception, alongside habituation and helplessness, as one of the outdoor workers described, "It is becoming more and more hot, but what do I do, ...I still have to go and work."
- **Interconnected vulnerabilities:** Their workplaces often lack basic amenities necessary for heat adaptation. The age- and gender-specific disadvantages further limit access. For example, women restrict their water intake because public toilets along the roads are inaccessible. The high prevalence of co-morbidities, particularly among elderly and women street vendors, adds another layer of vulnerability.
- **Early warnings as financial liability:** For a daily-wage worker from the informal sector, any warning that stops work is a loss of income. A worker who is offered money to stay home during a heatwave through parametric insurance may treat it as much-needed additional income rather than a reason not to work, complicating any behaviour change.



Evolving the Work: From Research to Contextual Solutions

Prayas is translating these signals into reports, tools, and partnerships, working towards contextual solutions along with appropriate heat-health communication:

- **Lived-experience reports:** The street vendor report *Braving the Heat: Learning from the Voices of the Street Vendors* has been published, with a series on manual labourers, construction workers, and others to follow.
- **Heat-health communication:** Developing simplified, relatable communication tools to improve risk awareness among vulnerable communities. In its previous work in rural areas, Prayas developed participatory learning approaches to help villages identify their own climate vulnerability.
- **Health system strengthening:** Engaging with the public and private sector primary health system for capacity building. As a first step, Prayas

collaborated with Pune Municipal Health Department and Pune Zilla Parishad to train more than 3,500 ASHAs. This was supported by a purpose-built educational booklet and handout.

- **Engagement with vulnerable community:** Ongoing efforts to reach out to collectives of outdoor workers to disseminate research findings, sensitize them about heat-health risks, and initiate a dialogue about the need for behaviour change and systemic level solutions.
- **Deliberation on existing solutions:** Review of the existing heat adaptive solutions from the community perspective and exploring their applicability to the context of Pune. e.g., In an analytical article *Parametric Insurance for Extreme Heat: Setting Right Expectations*, Prayas raises several regulatory and cost benefit considerations -e.g., who sets thresholds, who pays the premium, and whether compensation actually changes behaviour.

Barriers and Challenges

Prayas identifies several gaps that must be closed to strengthen the heat-health evidence base and to measure whether new interventions actually work:

- **Morbidity over mortality:** Existing heat health surveillance relies on heatstroke data, which are likely underreported, leading to an underestimate of the true burden. All-cause mortality and morbidity data are more useful indicators, but such data are sparsely accessible to individual researchers. The evidence on out-of-pocket expenditures, hospital/emergency care burden is also crucial. These issues are discussed in-depth in an analytical article *Beyond Strokes: How dangerous is extreme heat?*
- **Historical and hyperlocal climate data:** IMD weather-station data is available in real time, but the past decade of readings essential for understanding urban heat island patterns and overlaying on health data is either expensive to purchase or unavailable.
- **Socio-demographic data:** Basic figures such as the number of street vendors or public toilets in Pune may exist, but must be made accessible to inter-sectoral researchers.

Way Forward

Going forward, Prayas is trying to build relationships with community members to understand what kind of solutions will help them and how to implement and scale them. They will work on heat health communication betterment. Currently, it's done through advisory alerts, which make very little sense to people. Prayas is looking forward to reimagining this, for example, how to include heat in other health communications programs.

5.5 Lack of Evidence: The Structural Gap that Cuts across Everything

The single constraint that is cross-cutting across all four domains is the evidence base required to justify, calibrate, and scale heat-health interventions. Its absence has direct operational consequences like procurement decisions remain ad hoc, policy mandates remain unchanged, funders cannot justify capital costs, and programme designers cannot credibly claim that what they are deploying works, for whom, and under what conditions.

The specific evidence gaps include:

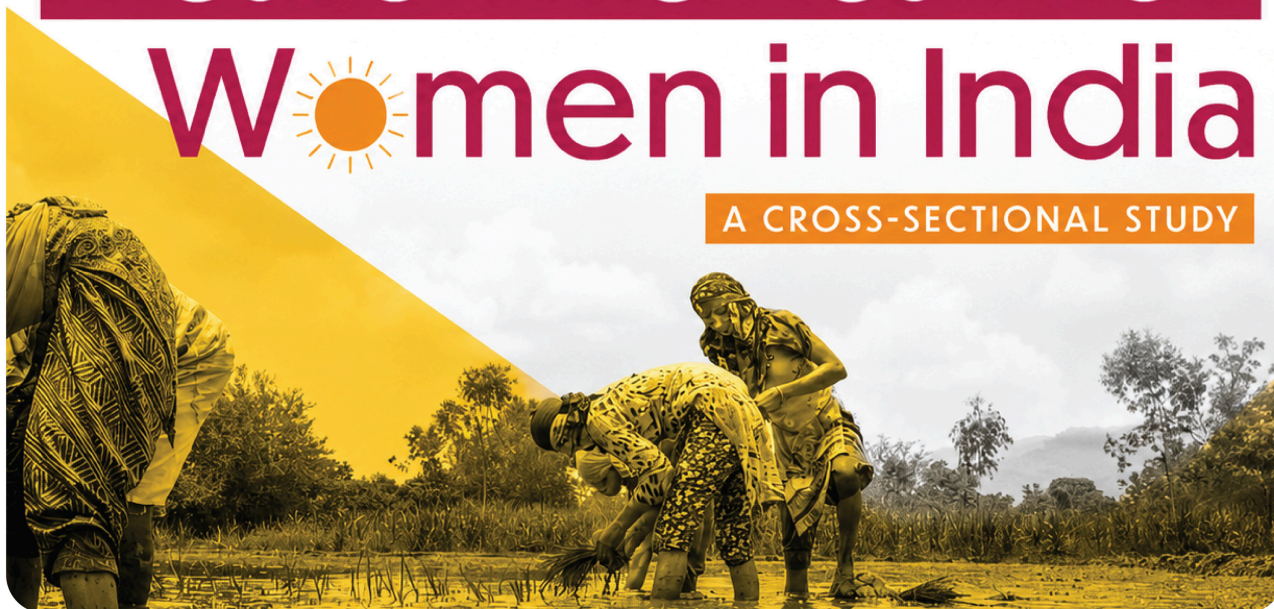
- **Cooling:** There is insufficient data on which personal cooling equipment types meaningfully reduce physiological heat stress in specific population groups, how it impacts long-term health outcomes and cost-effectiveness of cooling interventions (For e.g: Cool Roofs), and on the direct health benefits of urban greening in Indian contexts.
- **Digital Intelligence:** The effectiveness of EWS in driving community-level behaviour changes and reducing downstream heat-related morbidity and mortality has not been rigorously evaluated, and the evidence on telemedicine as a heat-health intervention despite the platforms existing has not been generated.
- **Health system strengthening:** The mortality and morbidity impact of deploying outreach clinics during heatwaves remain unmeasured. Evidence on enteric disease incidence during heatwave periods is sparse, and the interaction between heat and air pollution as compounding drivers of cardiovascular, respiratory, and mortality risk is systematically underexplored.
- **Behavioural solutions:** Evidence on which IEC approaches drive behaviour change and reduce heat-related morbidity, for which populations, and under what conditions remains insufficient to support strong programmatic claims.

What makes this evidence deficit particularly consequential is its self-reinforcing character. Weak evidence produces cautious policy. Cautious policy produces limited deployment. Limited deployment produces no new evidence. The cycle compounds year on year, while the climate trajectory worsens and the populations bearing the greatest heat burden continue to do so without adequate protection.

Breaking this cycle requires treating evidence generation not as a precondition for action, but as an integral component of action itself. Pilots must be designed with outcome measurement built in from the start. Innovations must be deployed with the data infrastructure required to evaluate them. And the findings must feed back into the policy systems, HAPs, health workforce training frameworks, procurement guidelines that determine what gets deployed at scale.

THE IMPACT OF Heat on the Health of Women in India

A CROSS-SECTIONAL STUDY



Building the Evidence Base for Heat–Health Adaptation: The Work of MS Swaminathan Research Foundation (MSSRF)

Framing the Problem: From Climate-Agriculture to Climate-Health

For over three decades, MSSRF has worked at the intersection of agriculture, livelihoods, and sustainable rural development. Its early recognition of climate variability as a risk to agrarian systems positioned the organisation ahead of the curve. What began as a focus on agricultural resilience has evolved into a deeper inquiry: how does climate change, particularly extreme heat, affect human health?

MSSRF identified a critical and underexplored gap: a lack of rigorous, context-specific evidence linking climatic factors to health outcomes, particularly among vulnerable populations. Heat adaptation, in practice, was being discussed in infrastructure and disaster management terms, but far less in terms of lived health impacts. MSSRF set out to address this gap, starting where evidence was limited and vulnerability highest.

Research Focus: How does climate change impact women and children across agroecological zones
MSSRF's first major inquiry centred on women and children, driven by two converging insights:

- Missing evidence on how climate change and the

resultant extreme weather events disproportionately affect women and children

- Explore the impact of climate hazards on the health, livelihoods, education and other aspects of women and children's lives in India

The initial scoping study by MSSRF emphasised that the climate change amplifies the existing social and health inequities. Women, children and socio-economically disadvantaged communities face disproportionate risks due to difference in exposure, adaptive capacity and access to resources. These findings reinstated the need for community-based research that generates locally relevant evidence to support equitable heat adaptation policies.

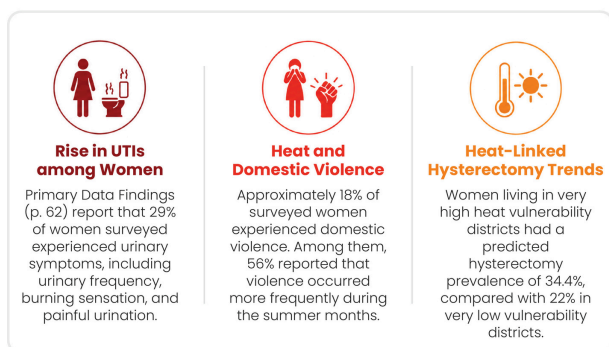


Decline in ANC visits- Only 49% of women attend all the four ANC visits in high heat-risk zone, compared to 80% in low-risk zones.

The impact of exposure to extreme drought on the women's health related indicators is evident. The study reveals a six percent higher likelihood of being underweight if a woman belongs to a drought-prone geography. Similarly, the likelihood of experiencing miscarriage or stillbirth is six percent higher in drought prone regions are compared to those who are not.

Emerging Signals from the Field

MSSRF deployed a triangulated mixed methods study to understand how heat affects women's physical, mental and reproductive health and their ability to access care. Primary surveys with around 3300 women across seven states including Bihar, Odisha, Maharashtra, Gujarat, Rajasthan, Tamil Nadu and Telangana to generate new evidence on heat-related symptoms, reproductive health issues and access to public infrastructure. A secondary data analysis of NFHS-5 data of those states were examined for physical health complaints and care-seeking patterns. In addition, focus group discussions among women were conducted along with national level consultations over 60 experts from civil societies, public health, academia, and government, surfacing policy and implementation insights.



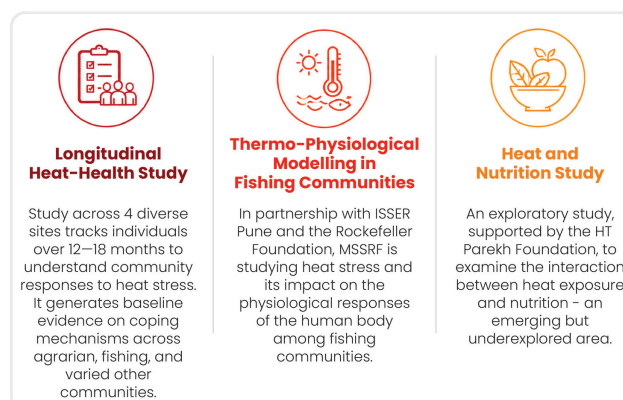
The survey findings showed that heat does not affect all women equally. The study confirmed that women in heat-prone districts experience amplified health risks due to rising temperatures with 70% of women reporting physical health symptoms including fatigue, dizziness, dehydration and gastrointestinal discomfort during peak heat months. Nearly 25% of them did not seek any health care facility. 18% of women experience any form of violence at least once in their household. The rural and semi-urban areas surveyed lacked basic heat adaptation infrastructure. Also, India has made significant progress in institutionalising heat action with over 300 Heat Action Plans (HAPs). They are weakly implemented and poorly tailored to local realities..

Core insights from MSSRF's ongoing initiatives reveal that extreme heat exacerbates existing infrastructural deficits, transforming environmental stress into direct health risks. Furthermore, these findings suggest that heat intensifies underlying social vulnerabilities as much as physiological ones, highlighting the multi-dimensional impact of rising temperatures on both health systems and human behaviour.

Evolving the Work: From Signals to Systems

MSSRF's initial research is not designed to drive immediate policy change, instead it generates evidence-based signals to inform relevant ecosystem partners and shape future research priorities. Building on this foundation, MSSRF is now advancing its heat and health evidence portfolio through three ongoing studies.

These studies are being conducted bringing in various academic institutions and government partners in India including Indian Institute of Science, ICMR-National Institute of Epidemiology, ART PARK, IMD, SCARF and keeping SDMA of respective states informed. The studies collect granular individual-level data (e.g., age, co-morbidities) that will eventually help to inform personalised, context-sensitive early warning systems, while also assessing the prevalence, reporting patterns, and hospitalisation rates of heat-related illnesses (HRIs). Findings will create a baseline community level database as well as aid the targeted development of heat adaptation interventions.



Way Forward: Future Research Priorities

Despite significant progress, MSSRF identifies two critical gaps that must be addressed to strengthen the evidence in Heat and Health:

- Molecular-Level Physiological Impacts:** Current research lacks depth regarding how extreme heat affects the human body at the molecular level. Closing this knowledge gap is essential to strengthening causal evidence, which will, in turn, refine clinical protocols and public health interventions.
- Granular Field Data Scarcity:** While macro-level datasets are available, there is a shortage of real-time, community-specific field data. MSSRF is uniquely positioned to bridge this gap by leveraging its deep-rooted ground presence to establish robust community-level baselines.

CHAPTER VI

Financing Heat-Health Adaptation in India: From Fragmentation to a Unified Innovation Platform



Chapter VI: Financing Heat-Health Adaptation in India: From Fragmentation to a Unified Innovation Platform

6.1 Why Financing Heat Adaptation is Different

The escalating impacts of climate change demand timely and sustained financial resources for adaptation. Global flows of adaptation finance reached \$65 billion in 2023–24 (Climate Policy Initiative, 2025), yet developing countries alone are estimated to require more than \$310 billion annually. This financing gap is particularly pronounced in the context of extreme heat, where costs are dispersed across sectors and rarely reflected within national and subnational budgets (Adaptation Gap Report 2025 | UNEP - UN Environment Programme, n.d.). Against this backdrop, financing heat health adaptation faces a fundamental governance challenge: heat stress is simultaneously a health crisis, an urban infrastructure challenge, a labour welfare issue, and a social equity emergency. No single government department owns it, no single budget line captures it, and no single funder can solve it. The question is how to finance heat-health adaptation efficiently enough that the available resources (often scarce) create the largest possible reduction in heat-related suffering.

6.2 Financing Architecture for Heat-Health Adaptation

Different adaptation activities require different types of investment. Broadly, five sources of funding support adaptation, each serving a different purpose.

Public finance

- **Government budgets and schemes:** It is the primary source of funding for large-scale and long-term implementation.
- **Development finance** provided by national and international development institutions complements public finance by offering concessional loans for infrastructure and large public projects, sometimes also includes funding for technical assistance.

Private Finance

- **Philanthropic funding** provides grants that can support new and untested ideas without expecting a financial return.
- **Corporate and CSR funding** supports projects through companies' annual CSR commitments, but these are usually short-term and project specific.
- **Commercial capital**, such as venture capital, debt instruments, and insurance, invests only where there are a clear business models and the potential for financial returns.

Financing adaptation is unlike financing mitigation projects, which often generate revenue through energy savings or carbon markets, most heat adaptation measures do not produce direct financial returns. Investments such as cooling shelters, heat surveillance systems, or early warning systems primarily reduce health risks and economic losses, with the benefits shared across society rather than captured by investors (Takacs et al., 2025). As a result, heat adaptation is largely a public responsibility, with governments playing a central role in financing it while leveraging development, philanthropic and private capital where appropriate.

6.2.1 Public Finance

Heat adaptation financing instruments should be seen in conjunction with the health financing architecture. The health financing system is anchored in the National Health Mission (NHM), which channels central government resources to states. Within this framework, the National Programme on Climate Change and Human Health (NPCCHH) is the primary vehicle for heat-health adaptation. Funding under NPCCHH is principally directed across three types of activities: facility infrastructure (heatstroke rooms, solarisation), health worker training and sensitisation, and IEC(NCDC | MOHFW, n.d.-b). The central government also channels a nucleus of funding through NDMA for HAPs implementation that is meant to catalyse broader state and district-level spending (Reports & Studies | NDMA, n.d.). The public finances can also be routed through existing sectoral schemes for example, passive cooling could be built into state-funded low-cost housing programmes.

A second tier of public finance is channelled through partnerships between governments and development finance institutions such as the National Bank for Agriculture and Rural Development (NABARD), the Housing and Urban Development Corporation (HUDCO), the Asian Development Bank (ADB), and the World Bank, which finance large infrastructure investments in cities, agriculture, and disaster risk reduction (A Livable Future: Protecting Jobs and Growth from Extreme Heat in South Asia's Cities, n.d.). ADB's climate resilience lending in India have begun to integrate cooling finance, but the health co-benefits of these investments (reduced heat-related morbidity, improved thermal comfort for pregnant women, lower incidence of heat exhaustion among outdoor workers, etc.) are not systematically measured or reported (ADB to Invest \$25 Million in Certified Climate Bond for Climate Financing in India | Asian Development Bank, n.d.). In such cases (when these co-benefits are invisible), they cannot be used to make the case for higher investment, and the virtuous cycle of evidence-to-finance never starts.

6.2.2 The private sector

Private financing particularly looking at funding the constellation of climate-tech innovations emerging in India's startup ecosystem, represents actors with a legitimate and increasingly urgent stake in heat-health adaptation. They follow a financing trajectory that is now well-understood in the global innovation ecosystem: initial small grants from philanthropy, followed by angel investment, and then institutional venture capital as the product enters the market. The private sector is financing productisation of innovation and acts as a lever to scale innovations, but it cannot finance the public-good components of an innovation such as R&D for long-term sustainability research eco-friendly materials, embodied carbon reduction etc.

Commercial actors also include the insurance sector, which is beginning to recognise extreme heat as a systemic risk. Parametric insurance instruments that trigger payouts when temperature thresholds are exceeded (linked to health system costs or labour income losses) are being explored in India with initial funding coming from philanthropic actors and then being taken up by the traditional insurance actors from various banks. These are signals of creating a market incentive for preventive heat-health adaptation investments.

Philanthropic finance has been one of the earliest and the most influential sources of capital in the heat-health adaptation ecosystem. It has funded interventions like early research on climate and health vulnerability, pilots of innovative technologies that have no revenue model in a place or no proven outcomes etc. Governments are often unable to finance interventions that remain unproven, and commercial capital will not fund what earns no return. Philanthropy fills this critical gap by assuming early-stage risk, and a significant share of what is now regarded as established knowledge on heat and health in India originated through philanthropic grants. However, currently evidence generation is grant-dependent, project-bounded, and often siloed. ("No Country for Aid Alone: Strategic Partnerships for Development Finance," 2026) The moment a grant ends, a data system that cost millions to build may go unmaintained. A community health intervention demonstrated in one district cannot be replicated in the next without securing another full round of funding. The cumulative result is that philanthropy has financed many proofs of concept but very few journeys from proof to scale.

6.3 The Case for Expanding the Tent: Partners with Adjacent Mandates

The multi-dimensional nature of heat stress means that actors whose primary mandate lies adjacent to health (urban infrastructure, green spaces, energy efficiency, water security, housing, occupational welfare) are in fact financing (or failing to finance) heat-health outcomes whether they acknowledge it or not.

Urban greening and tree cover programmes, financed through Smart Cities Mission budgets, municipal corporations, and green infrastructure funds, directly reduce ambient temperatures in urban areas. Each percentage point increase in urban tree canopy is associated with measurable reductions in heat-related morbidity. (Takacs et al., 2025) A funder whose stated goal is biodiversity conservation or urban air quality improvement is simultaneously, even if unintentionally, financing a heat-health intervention. The question is whether that co-benefit is measured, whether it is attributed, and whether it is used to mobilise additional resources.

Funder Type	Primary Role in Heat-Health Adaptation	Typical Investment Focus
Government (Central, State and Local)	Finances large-scale implementation, integrates interventions into public systems, and sustains long-term operations	Heat Action Plans, health system preparedness, surveillance systems, early warning dissemination, workforce training, cooling centres, public infrastructure, last-mile service delivery, and social protection
Development Finance Institutions (Multilateral and Bilateral)	Provide concessional finance and technical assistance for large-scale adaptation investments, policy reforms, and institutional strengthening	Climate-resilient health infrastructure, urban resilience, water and cooling infrastructure, digital public systems, capacity building, programme scale-up, and blended finance
Philanthropic Foundations and Trusts	De-risk early-stage innovation by providing flexible grant funding for pilots, validation, and evidence generation	Proof-of-concept pilots, implementation research, innovation grants, ecosystem building, policy engagement, technical assistance, and catalytic funding
Corporate and CSR	Support community programmes, employee resilience, and local implementation through project-based funding and partnerships	Workplace heat protection, occupational health programmes, cooling products, awareness campaigns, community outreach, district pilots, and CSR-funded public infrastructure
Private Equity, Venture Capital, and Impact Investors	Scale commercially viable solutions with sustainable business models and revenue potential	Digital health platforms, diagnostics, cooling technologies, wearable devices, climate-risk analytics, insurance products, and other scalable heat-health technologies
Academia Funders	Generate evidence to inform policy, innovation, and implementation through research and evaluation	Climate-health research, epidemiological studies, surveillance tools, climate modelling, implementation science, technology validation, academic partnerships, and impact evaluation

The principle is straightforward: heat-health adaptation is an outcome that can be financed through instruments whose mandate are housing, greening, water, energy, occupational safety, or insurance. The challenge is creating the incentive structure, the measurement framework, and the coordination mechanism that makes those co-benefits visible and attributable. Once they are visible, they can be claimed, reported, and used to abandon siloed approaches and bring efficiency in utilising limited resources and unlocking more from the other stakeholders.

The innovation ecosystem that has emerged around heat-health adaptation in India reflects a rich diversity of financing models, each suited to a different stage of the innovation lifecycle. Mapping these financing pathways reveals not only how innovation is currently funded, but also the challenges involved in taking innovative solutions from pilot projects to system-wide adoption through government programmes and budgets.

6.4 Financing Innovative Solutions

Innovation Type	Primary Financing Sources	Why this financing is appropriate	Key Challenges
Fundamental Research (e.g., heat vulnerability mapping, longitudinal research studies on Heat and Health)	Philanthropic grants, university research grants, government research funding	Evidence is a public good, no single investor can capture its returns. Foundations and Universities provide patient, unrestricted capital to generate knowledge that eventually shapes policy and unlocks larger funding streams.	Fragmented across organisations and geographies. Limited cumulative learning. Knowledge dissipates when grants end.
Prototype & Validation (e.g., pilot cooling technologies, AI models, diagnostics, digital tools)	Philanthropic capital, Venture Capital	Early-stage capital helps develop, test, and validate innovations before they become commercially or operationally viable.	Many innovations face a "missing middle" where funding is insufficient to move from successful pilots to large-scale validation and deployment.
Product Development & Market Readiness (e.g., regulatory approval, manufacturing, commercialisation of technologies)	Philanthropic capital, Equity investment, venture capital, blended finance	Private investment supports product refinement, manufacturing, market entry, and business growth once technical feasibility has been demonstrated.	Commercial risks, uncertain market demand, and limited procurement pathways often constrain investment and scale-up.
Scale-up & Government Adoption (e.g., integration into Heat Action Plans, public health programmes, government procurement)	Government budgets, development finance institutions, CSR	Governments are best positioned to finance large-scale implementation, while philanthropy and development partners support demonstration projects that build the evidence for public investment.	Many Heat Action Plans lack dedicated financing, and limited evidence on cost-effectiveness slows adoption into government programmes and budgets.
Long-term Operations & Sustainability (e.g., maintenance of surveillance systems, digital platforms, training, monitoring and evaluation)	Government budgets, service contracts, recurrent public financing	Sustainable financing is needed to maintain systems, strengthen institutional capacity, and ensure innovations continue to deliver public value over time.	Recurrent operational funding is often overlooked, resulting in poorly maintained systems and limited long-term sustainability.

6.5 Towards an Integrated Financing Architecture

The financing limitations described above characterised by fragmented philanthropy, marginal public allocations, weak cross-sectoral linkages, and the missing middle between demonstrated innovation and scaled implementation all point toward the same structural solution: a coordinated, multi-stakeholder financing platform that integrates the full cycle of heat-health adaptation finance, from evidence generation to implementation at scale. This could be operationalised through the following financing mechanisms:

- **Pooled philanthropy:** Rather than individual foundations funding parallel, siloed projects, a pooled philanthropy mechanism would allow co-funding opportunities. This would immediately reduce duplication, lower the cost per unit of benefits generated, and create a common reference point that all funders, governments, and implementers can use.
- **Patient capital for the missing middle:** A sub-fund within the platform, structured as a five-to-seven-year patient capital pool would allow innovators who have demonstrated their impact in one geography to systematically expand, build a playbook, and lower their unit costs through learning and standardisation, and create scalable, replicable models better tuned for sustainable adoption.
- **Technical assistance for government mainstreaming:** The most durable form of heat-health adaptation finance is a change in government fiscal planning specifically, the inclusion of heat-health-relevant targets and activities in PIP and ROP submissions. A technical assistance facility, drawing on the capabilities of organisations building climate and health innovations, evidence for strengthening health systems or supporting policy frameworks (for example Civic Data Lab, Khushi Baby, MHT, CSTEP, CEEW etc) could support and work with government staff. Over time, as the evidence base grows and the institutional confidence increases, this could enable a meaningful upward revision of state allocations.
- **Outcome-based financing at the district level:** The innovative element of the integrated financing architecture is the gradual introduction of outcome-based financing mechanisms, instruments in which funding is contingent on achievement of agreed health outcomes.

As some CSOs have argued, the next cycle of financing should explore whether specific outcomes (training of district and division-level officials on heat-health data platforms, reduction in NCD burden in heat hotspots, protection of community health workers during heatwaves) can be the basis for performance-linked payment structures. This would create a direct financial incentive for government actors to invest in the activities that produce outcomes, rather than the activities that merely fulfil budget line requirements.

The long-term goal of any heat-health adaptation financing strategy must be to move the cost of proven interventions from grants to government budgets. For it to happen, the evidence must be compelling, the cost must be known, the implementation model must be standardised, and the political champions within government must be enabled to make the case for adoption.

The key point is to recognise that efficiency with which evidence is generated, shared, and converted into policy and practice is itself a form of impact. Every rupee of philanthropic capital that enables a government to finance a proven intervention at scale with public money has a multiplier effect. Every piece of evidence generated in one state that spares another state the cost of re-proving the same thing reduces waste. Every data platform that replaces three duplicate dashboards with a single shared operating system frees resources for delivery. And every district official trained to make the case for heat-health investment in their annual budget negotiation is a permanent institutional asset that no project grant can create.

CHAPTER VII

Call to Action



Chapter VII: Call to Action

India Health Fund began its work in climate and health adaptation considering the profound impact of climate change on infectious diseases, particularly vector-borne diseases. As IHF expanded its understanding, it became clear that the climate crisis is reshaping a much broader spectrum of health outcomes. Heat stress emerged as one of the most urgent and rapidly growing public health threats. While the scale of the heat-health burden is increasingly recognised, the ecosystem responding to it remains fragmented. Promising solutions exist, but they are scattered across sectors and geographies. Evidence remains limited, investments are disconnected, and few mechanisms link innovation to implementation and, ultimately, scale. The result is a landscape of isolated pilots rather than a coherent pathway to improved health impact.

Recognising the need for a more integrated and evidence-driven approach (de Bont et al., 2024) India Health Fund committed to orchestrating a stronger heat adaptation ecosystem; one that connects research, innovation, and implementation, while generating the evidence needed to inform policy and strengthen resilience within public systems.

With that commitment, IHF moved from intent to action. The Climate & Health Hackathon, developed in partnership with NIMS University, Ashoka University, and Swissnex, was first of its kind to surface and accelerate ideas at the frontier of research and innovation, with heat adaptation as a central theme. The Asia-wide Climate × Health Lighthouse Challenge, run in partnership with AVPN, Prudence Foundation, and Bayer Foundation, explicitly prioritised solutions to reduce heat stress and innovations in heat-stable diagnostics. Further, the Climate Innovation Challenge, with UNICEF and the Cambridge Institute for Sustainability Leadership, asked a harder question: what does it take to protect children's health from climate risk at scale? Each initiative generated insights alongside solutions, but together they revealed a persistent gap not only in research, but in the infrastructure needed for successful adoption of innovative technologies within public systems.

Drawing on its learning across these Climate & Health initiatives, IHF is stepping forward as a lead convenor and coordinator of a cross-sector heat-health collaborative. This role builds on IHF's unique position at the intersection of health innovation and public-sector partnerships, bringing together the actors, evidence, and capital needed to move heat adaptation from promising ideas to impact. But convening alone is not enough. The scale and urgency of the challenge demand a different kind of engagement from every stakeholder in the ecosystem:

- **Governments and state health departments:** the tools are emerging; what they need now is a pathway into public systems. Early warning systems embedded within district health offices, heat-health surveillance integrated into HMIS platforms, and Heat Action Plans with explicit strategies for integrating and scaling innovations. IHF is willing to co-design these pathways with state partners.
- **Research institutions and academic partners:** the field needs translational research that connects climate hazards to health outcomes and health outcomes to actionable interventions. A multidisciplinary, systems-thinking approach that maps hazard-to-vulnerability-to-outcome pathways and is designed from the outset to generate evidence that can inform investment, policy, and implementation.
- **Philanthropic and institutional funders:** the case for a dedicated, pooled financing facility for coordinated, end-to-end heat-health adaptation has never been stronger. IHF's experience with the Lighthouse Fund demonstrates that catalytic, structured funding supported by rigorous evaluation frameworks and clear government-alignment can unlock a quality and pipeline of innovation that conventional open-grant models rarely achieve. Co-investing offers one of the highest-leverage entry points for translating innovation into population-level impact.
- **Private sector and technology innovators:** the market for heat-health adaptation in India and across Asia is real, underserved, and growing. Solutions that can demonstrate clinical and operational effectiveness, integrate with public health systems, and achieve cost structures viable for LMIC contexts will be positioned not only for funding, but for adoption and scale.

Heat is not a future risk. In India, it is already arriving earlier, staying longer, and killing people who have no means to escape it.

Reference

:: Finance Commission, India :: (n.d.). Retrieved August 13, 2026, from <https://fincomindia.nic.in/commission-reports-sixteenth>

A Livable Future: Protecting Jobs and Growth from Extreme Heat in South Asia's Cities. (n.d.). Retrieved August 14, 2026, from <https://www.worldbank.org/en/region/sar/publication/a-livable-future-protecting-jobs-and-growth-from-extreme-heat-in-south-asia-s-cities>

Adaptation Gap Report 2025 | UNEP - UN Environment Programme. (n.d.). Retrieved August 14, 2026, from <https://www.unep.org/resources/adaptation-gap-report-2025>

ADB to Invest \$25 Million in Certified Climate Bond for Climate Financing in India | Asian Development Bank. (n.d.). Retrieved August 14, 2026, from <https://www.adb.org/news/adb-invest-25-million-certified-climate-bond-climate-financing-india>

Ageing and health India. (n.d.). Retrieved August 13, 2026, from <https://www.who.int/india/health-topics/ageing>

Ambiator - Cooling without warming the Planet. (n.d.). Retrieved August 14, 2026, from <https://www.ambiator.com/>

Anikeeva, O., Hansen, A., Varghese, B., Borg, M., Zhang, Y., Xiang, J., & Bi, P. (2024). The impact of increasing temperatures due to climate change on infectious diseases. *BMJ*, 387.

<https://doi.org/10.1136/BMJ-2024-079343>

Aurassure. (n.d.). Retrieved August 14, 2026, from <https://aurassure.com/>

Bassey, P. U., Ngwu, F. A., Shimobi, O. C., Isiaka, A. B., God'swill, C. C., Hosein, C., & Ephraim-Emmanuel, B. C. (2025). Heat-related illnesses: a scoping review of health system strategies, emergency responses and interventions in heat-prone areas. In *BMC Public Health* (Vol. 25, Number 1). BioMed Central Ltd. <https://doi.org/10.1186/s12889-025-24012-4>

Bhawra, J., Ibrahim, S. T., Patel, J., Khadilkar, A. V., & Katapally, T. R. (2025). Climate Care India: A protocol for digital transformation of health systems for non-communicable disease management and climate change adaptation. <https://doi.org/10.1101/2025.05.25.25328322>

Castro, J. R. R., & Delina, L. L. (2025). Enhancing ICT utilisation for urban extreme heat adaptation: Perspectives from Southeast Asia. *Sustainable Futures*, 10. <https://doi.org/10.1016/j.sfr.2025.101368>

Census tables | Government of India. (n.d.). Retrieved August 13, 2026, from <https://censusindia.gov.in/census.website/data/census-tables>

Chapman, C. L., Johnson, B. D., Parker, M. D., Hostler, D., Pryor, R. R., & Schlader, Z. (2020). Kidney physiology and pathophysiology during heat stress and the modification by exercise, dehydration, heat acclimation and aging. *Temperature: Multidisciplinary Biomedical Journal*, 8(2), 108. <https://doi.org/10.1080/23328940.2020.1826841>

Climate Investment Opportunities in India's Cooling Sector. (2022). Climate Investment Opportunities in India's Cooling Sector. <https://doi.org/10.1596/38340>

COMMUNITY HATS • The Lakshmi Mittal and Family South Asia Institute. (n.d.). Retrieved August 14, 2026, from <https://mittalsouthasiainstitute.harvard.edu/community-hats/>

Cooling PPE for the World's Hottest Workplaces — Sukoon. (n.d.). Retrieved August 14, 2026, from <https://www.thesukoonworld.com/>

- Damtew, Y. T., Tong, M., Varghese, B. M., Anikeeva, O., Hansen, A., Dear, K., Zhang, Y., Morgan, G., Driscoll, T., Capon, T., & Bi, P. (2023). Effects of high temperatures and heatwaves on dengue fever: a systematic review and meta-analysis. *EBioMedicine*, 91, 104582. <https://doi.org/10.1016/J.EBIOM.2023.104582>
- Das, S., Ghosh, A., Hazra, S., Ghosh, T., Safra de Campos, R., & Samanta, S. (2020). Linking IPCC AR4 & AR5 frameworks for assessing vulnerability and risk to climate change in the Indian Bengal Delta. *Progress in Disaster Science*, 7, 100110. <https://doi.org/10.1016/J.PDISAS.2020.100110>
- Dasgupta, R., Dasgupta, P., Dayal, V., Mishra, A., Murali, A., Sharma, G., & Pany, P. (2025). Heat action plans in eight Indian cities: Knowledge gaps & opportunities for intersectoral heat governance. *Indian Journal of Medical Research*, 162(3), 330–341. https://doi.org/10.25259/IJMR_1019_2025
- de Bont, J., Nori-Sarma, A., Stafoggia, M., Banerjee, T., Ingole, V., Jaganathan, S., Mandal, S., Rajiva, A., Krishna, B., Kloog, I., Lane, K., Mall, R. K., Tiwari, A., Wei, Y., Wellenius, G. A., Prabhakaran, D., Schwartz, J., Prabhakaran, P., & Ljungman, P. (2024). Impact of heatwaves on all-cause mortality in India: A comprehensive multi-city study. *Environment International*, 184. <https://doi.org/10.1016/j.envint.2024.108461>
- Dey, A. K., Dimitrova, A., Raj, A., & Benmarhnia, T. (2025). Heatwaves and Home Births: Understanding the Impact of Extreme Heat on Place of Delivery in India. *GeoHealth*, 9(11). <https://doi.org/10.1029/2025GH001540>
- Di Napoli, C., Barnard, C., Prudhomme, C., Cloke, H. L., & Pappenberger, F. (2021). ERA5-HEAT: A global gridded historical dataset of human thermal comfort indices from climate reanalysis. *Geoscience Data Journal*, 8(1), 2–10. <https://doi.org/10.1002/GDJ3.102>
- Dube, K., Al Ali, H., Khan, B., & Daneshkhah, A. (2025). Heatwaves and Public Health: A Bibliometric Exploration of Climate Change Impacts and Adaptation Strategies. In *Climate* (Vol. 13, Number 12). Multidisciplinary Digital Publishing Institute (MDPI). <https://doi.org/10.3390/cli13120249>
- Ecofrost - Solar Powered Cold Storage Room Manufacturer in India - Ecozen | Ecozen. (n.d.). Retrieved August 14, 2026, from <https://www.ecozensolutions.com/ecofrost>
- Falchetta, G., De Cian, E., Sue Wing, I., & Carr, D. (2024). Global projections of heat exposure of older adults. *Nature Communications* 2024 15:1, 15(1), 3678-. <https://doi.org/10.1038/s41467-024-47197-5>
- Fritz, M. (2026). The mental health toll of heat stress in India. *Journal of Environmental Economics and Management*, 138, 103348. <https://doi.org/10.1016/J.JEEM.2026.103348>
- Gagnon, D., Schlader, Z. J., & Jay, O. (2026). The Physiology behind the Epidemiology of Heat-Related Health Impacts. In *Physiology* (Vol. 41, Number 1). American Physiological Society. <https://doi.org/10.1152/physiol.00012.2025>
- Gkouliaveras, V., Kalogiannidis, S., Kalfas, D., & Kotsas, S. (2025). Effects of Climate Change on Health and Health Systems: A Systematic Review of Preparedness, Resilience, and Challenges. In *International Journal of Environmental Research and Public Health* (Vol. 22, Number 2). Multidisciplinary Digital Publishing Institute (MDPI). <https://doi.org/10.3390/ijerph22020232>
- Hacopian, M. T., Barrón-Sandoval, A., Romero-Olivares, A. L., Berlemont, R., & Treseder, K. K. (2025). Warming is Associated With More Encoded Antimicrobial Resistance Genes and Transcriptions Within Five Drug Classes in Soil Bacteria: A Case Study and Synthesis. *Environmental Microbiology*, 27(4), e70097. <https://doi.org/10.1111/1462-2920.70097>

Heat and health. (n.d.). Retrieved August 13, 2026, from <https://www.who.int/news-room/fact-sheets/detail/climate-change-heat-and-health>

Home | India Meteorological Department. (n.d.). Retrieved August 13, 2026, from <https://mausam.imd.gov.in/>

Hot Take- Cool Roof Research Study Report 2024 - Mahila Housing Trust. (n.d.). Retrieved August 14, 2026, from <https://www.mahilahousingtrust.org/knowledgehub/hot-take-cool-roof-research-study-report-2024/>

How can Heat Action Plans Make Thane a Heat-Resilient City? (n.d.). Retrieved August 14, 2026, from <https://www.ceew.in/publications/how-can-thane-city-tackle-heatwaves-risks-with-heat-action-plan>

How we build scientific Heat Action Plans with Indian cities | CEEW. (n.d.). Retrieved August 13, 2026, from <https://www.ceew.in/blogs/scientific-heat-action-plans-indian-cities>

ICMR-NIOHR Official Website - ICMR-NIOHR. (n.d.). Retrieved August 14, 2026, from <https://nioh.org/>
Impact of Extreme Heat on Gig Workers: A Survey Report – Telangana Gig and Platform Workers Union. (n.d.). Retrieved August 13, 2026, from <https://tgpuw.org/2024/08/17/impact-of-extreme-heat-on-gig-workers-a-survey-report/>

Inclusive Finance and Extreme Heat: How Small Loans and Parametric Insurance Can Help Vulnerable Populations Manage Through Deadly Heat Waves. April 2023 - Mahila Housing Trust. (n.d.). Retrieved August 14, 2026, from https://www.mahilahousingtrust.org/mht_media/inclusive-finance-and-extreme-heat-how-small-loans-and-parametric-insurance-can-help-vulnerable-populations-manage-through-deadly-heat-waves/

India - Country Overview | Climate Change Knowledge Portal. (n.d.). Retrieved August 13, 2026, from <https://climateknowledgeportal.worldbank.org/country/india>

Ioannou, L. G., Foster, J., Morris, N. B., Piil, J. F., Havenith, G., Mekjavic, I. B., Kenny, G. P., Nybo, L., & Flouris, A. D. (2022). Occupational heat strain in outdoor workers: A comprehensive review and meta-analysis. *Temperature: Multidisciplinary Biomedical Journal*, 9(1), 67. <https://doi.org/10.1080/23328940.2022.2030634>

Islam, S., Karipot, A., Rohini Bhawar, ·, Palash Sinha, ·, Kedia, S., & Khare, · Manoj. (2024). Urban heat island effect in India: a review of current status, impact and mitigation strategies. *Discover Cities* 2024 1:1, 1(1), 34-. <https://doi.org/10.1007/S44327-024-00033-3>

Kc, A., & Vaezghasemi, M. (2025). 'Too much, too little'—heat wave impact during pregnancy and the need for adaptation measures. *Global Health Action*, 18(1). <https://doi.org/10.1080/16549716.2025.2476277>
Khushi Baby: IHF. (n.d.). Retrieved August 14, 2026, from <https://www.indiahealthfund.org/khushi-baby/>

Krishnan, R., Sanjay, · J, Chellappan, ·, Milind Mujumdar, G. ·, Kulkarni, A., & Chakraborty, S. (n.d.). Assessment of Climate Change over the Indian Region A Report of the Ministry of Earth Sciences (MoES), Government of India.

Kumar, A., Mahajan, N. P., Sorokhaibam, R., Sunthlia, A., Babu, B. S., Vardhan, S., & Shrivastava, A. (2020). National programme on climate change and human health-india, 2019. *Journal of Communicable Diseases*, 52(3), 43–48. <https://doi.org/10.24321/0019.5138.202029>

Lakhoo, D. P., Brink, N., Radebe, L., Craig, M. H., Pham, M. D., Haghighi, M. M., Wise, A., Solarin, I., Luchters, S., Maimela, G., Chersich, M. F., Hetem, R. S., Strehlau, R., Boeckmann, M., Harden, L., Technau, K. G., Brimicombe, C., Wright, C. Y., Nakstad, B., ... Chersich, M. (2025). A systematic review and meta-analysis of heat exposure impacts on maternal, fetal and neonatal health. *Nature Medicine*, 31(2), 684–694. <https://doi.org/10.1038/s41591-024-03395-8>

Lugten, E., & Hariharan, N. (2022a). Strengthening Health Systems for Climate Adaptation and Health Security: Key Considerations for Policy and Programming. *Health Security*, 20(5), 435–439. <https://doi.org/10.1089/hs.2022.0050>

Lugten, E., & Hariharan, N. (2022b). Strengthening Health Systems for Climate Adaptation and Health Security: Key Considerations for Policy and Programming. *Health Security*, 20(5), 435–439. <https://doi.org/10.1089/hs.2022.0050>

March, H., Meehan, K., Domene, E., Satorras, M., & Saurí, D. (2026). Why water security matters to cities under extreme heat in the Global North. In *npj Urban Sustainability* (Vol. 6, Number 1). Springer Nature. <https://doi.org/10.1038/s42949-025-00317-6>

McLeod, K. B., & Goering, L. (2025). As Extreme Heat Threats Grow, Can Heat Insurance Offer Protection? In *Journal of City Climate Policy and Economy* (Vol. 3, Numbers 2–3, pp. 215–222). University of Toronto Press. <https://doi.org/10.3138/jccpe-2024-0044>

Meher, M. M., Afrin, M., Bayazid, A. Al, Islam, M. S., & Ali, M. Z. (2025). Deciphering the impact of heat wave in the global surge of infectious diseases. In *Hygiene and Environmental Health Advances* (Vol. 15). Elsevier B.V. <https://doi.org/10.1016/j.heha.2025.100135>

Ministry of Health & Family Welfare Government of India National Centre for Disease Control Government of India NATIONAL PROGRAMME ON CLIMATE CHANGE AND HUMAN HEALTH (NPCCHH). (n.d.).

Mishra, S., Verma, P., Patidar, N., Katira, J. M., Gaonkar, N., Solanki, J., Tadv, R., Yasobant, S., & Saxena, D. B. (2025). Building climate resilient healthcare systems through interventions in Gujarat India. *Discover Public Health*, 22(1). <https://doi.org/10.1186/s12982-025-00659-7>

Mora, C., McKenzie, T., Gaw, I. M., Dean, J. M., von Hammerstein, H., Knudson, T. A., Setter, R. O., Smith, C. Z., Webster, K. M., Patz, J. A., & Franklin, E. C. (2022). Over half of known human pathogenic diseases can be aggravated by climate change. *Nature Climate Change*, 12(9), 869–875. <https://doi.org/10.1038/s41558-022-01426-1>

Naskar, P. R., Mohapatra, M., Singh, G. P., & Das, U. (2024). Spatiotemporal variations of UTCI based discomfort over India. *Journal of Earth System Science*, 133(1). <https://doi.org/10.1007/s12040-024-02261-y>

NCDC | MOHFW. (n.d.-a). Retrieved August 13, 2026, from <https://ncdc.mohfw.gov.in/includes/About/CentresAndDivision/CEOH.php>

NCDC | MOHFW. (n.d.-b). Retrieved August 13, 2026, from https://ncdc.mohfw.gov.in/includes/Resource_Library/index.php?tab=Technical%20Guidelines

NFHS. (n.d.). Retrieved August 13, 2026, from <https://www.nfhsiips.in/nfhsuser/nfhs5.php>

No Country for Aid Alone: Strategic Partnerships for Development Finance. (2026). No Country for Aid Alone: Strategic Partnerships for Development Finance. <https://doi.org/10.64503/978-93-49061-58-3>

O'Donnell, D., & Sovacool, B. K. (2026). Cities need an integrated and holistic approach to health adaptation in climate planning. *Nature Cities*, 3(1), 38–47. <https://doi.org/10.1038/s44284-025-00364-1>

Parametric Insurance for Extreme Heat: Setting right expectations. (n.d.). Retrieved August 14, 2026, from <https://energy.prayaspune.org/our-work/article-and-blog/parametric-insurance-for-extreme-heat>

Patil, S., Miyajiwala, A., Arora, A., Raj, A., Thakkar, H., Takalikar, M. S., & Zadey, S. (2025). Geospatial Accessibility to Primary and Community Health Centres in India. *MedRxiv*, 2025.05.13.25327502. <https://doi.org/10.1101/2025.05.13.25327502>

Prabhu, S., Suresh, K. A., Mandal, S., Sharma, D., & Chitale, V. (2025). How Extreme Heat is Impacting India Assessing District-level Heat Risk | Report.

Press Note Details: Press Information Bureau. (n.d.). Retrieved August 13, 2026, from <https://www.pib.gov.in/PressNoteDetails.aspx?NotelD=151925&ModuleId=3®=3&lang=1>

Press Release Page | Press Information Bureau. (n.d.). Retrieved August 13, 2026, from <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2296309®=48&lang=1>

Ravindra, K., Bhardwaj, S., Ram, C., Goyal, A., Singh, V., Venkataraman, C., Bhan, S. C., Sokhi, R. S., & Mor, S. (2024). Temperature projections and heatwave attribution scenarios over India: A systematic review. *Heliyon*, 10(4), e26431. <https://doi.org/10.1016/J.HELİYON.2024.E26431>

Reports & Studies | NDMA. (n.d.). Retrieved August 13, 2026, from <https://ndma.gov.in/reports-studies>

Romanello, M., Walawender, M., Hsu, S. C., Moskeland, A., Palmeiro-Silva, Y., Scamman, D., Smallcombe, J. W., Abdullah, S., Ades, M., Al-Maruf, A., Ameli, N., Angelova, D., Ayeb-Karlsson, S., Ballester, J., Basagaña, X., Bechara, H., Beggs, P. J., Cai, W., Campbell-Lendrum, D., ... Costello, A. (2025). The 2025 report of the Lancet Countdown on health and climate change: climate change action offers a lifeline. *The Lancet*, 406(10521), 2804–2857. [https://doi.org/10.1016/S0140-6736\(25\)01919-1](https://doi.org/10.1016/S0140-6736(25)01919-1)

Saad, S., Adede, C., Citrin, D., Wasunna, B., Barasa, M., Jafa, K., & Ebi, K. L. (2025). Climate-related stressors, community healthcare systems, and adaptation strategies: A scoping review. In *Journal of Climate Change and Health* (Vol. 26). Elsevier Masson s.r.l. <https://doi.org/10.1016/j.joclim.2025.100574>

Scheelbeek, P. F. D., Dangour, A. D., Jarmul, S., Turner, G., Sietsma, A. J., Minx, J. C., Callaghan, M., Ajibade, I., Austin, S. E., Biesbroek, R., Bowen, K. J., Chen, T., Davis, K., Ensor, T., Ford, J. D., Galappaththi, E. K., Joe, E. T., Musah-Surugu, I. J., Alverio, G. N., ... Berrang-Ford, L. (2021). The effects on public health of climate change adaptation responses: A systematic review of evidence from low- And middle-income countries. In *Environmental Research Letters* (Vol. 16, Number 7). IOP Publishing Ltd. <https://doi.org/10.1088/1748-9326/ac092c>

SEWA's journey towards climate resilience. (2026). <https://doi.org/10.54394/00033621>

Shah, A., Sugathan, A., Malghan, D., Kim, R., & Subramanian, S. V. (2025). Spatiotemporal changes in heat stress exposure in India, 1981-2023. *Nature Communications* 2025 16:1, 16(1), 9496-. <https://doi.org/10.1038/s41467-025-64840-x>

Singh, C., Vyas, D., Patil, S., Ranjit, N., Poonacha, P., & Surampally, S. (2024). How are Indian cities adapting to extreme heat? Insights on heat risk governance and incremental adaptation from ten urban Heat Action Plans. *PLOS Climate*, 3(11). <https://doi.org/10.1371/JOURNAL.PCLM.0000484>

Sorensen, C., & Hess, J. (2022). Treatment and Prevention of Heat-Related Illness. *New England Journal of Medicine*, 387(15), 1404–1413.

<https://doi.org/10.1056/NEJMCP2210623;SUBPAGE:STRING:METEREDCONTENT>

Soundararajan, S., Bagepally, B. S., Dhingra, J., Dinesh, M. P., Nimithamohan, K., & Balachandar, R. (2025). Modelling the relationship between extreme temperature metrics and cardiovascular disease burden in India: Insights from a multi-state study on climate change challenges for 2011–2019. *Clinical Epidemiology and Global Health*, 34. <https://doi.org/10.1016/j.cegh.2025.102084>

State of the Climate in Asia in 2024. (n.d.). Retrieved August 13, 2026, from <https://storymaps.arcgis.com/stories/6dbde654cb464306a692811e8bc64de8>

Takacs, S., Souverijns, N., Jones, N., Tiwari, A., & Kikutani, N. (2025). Prioritizing heat adaptation measures across Indian cities: a benefit-cost analysis. *Npj Urban Sustainability*, 5(1). <https://doi.org/10.1038/s42949-025-00271-3>

Tamim, A. R., Patwary, M. M., Bardhan, M., Badhon, M. I. A., Rahman, M. S., Sakib, I. C., Iftikhar, A., Kabir, M. P., Pitol, M. N. S., Saha, C., & Browning, M. H. E. M. (2025). Occupational Heat Risk Perceptions and Behavioral Adaptation Strategies Among Construction and Welding Workers in Bangladesh. <https://doi.org/10.21203/rs.3.rs-8123494/v1>

The Fifth Assessment Report of the IPCC | UNFCCC. (n.d.). Retrieved August 13, 2026, from <https://unfccc.int/topics/science/workstreams/cooperation-with-the-ipcc/the-fifth-assessment-report-of-the-ipcc>

The synergies of heat stress and air pollution and its health impacts. (n.d.-a). Retrieved August 13, 2026, from <https://www.who.int/publications/i/item/B09369>

The synergies of heat stress and air pollution and its health impacts. (n.d.-b). Retrieved August 13, 2026, from <https://www.who.int/publications/i/item/B09369>

Thermal comfort indices time-series derived from ERA5 reanalysis. (n.d.). Retrieved August 13, 2026, from <https://cds.climate.copernicus.eu/datasets/derived-utci-historical-timeseries?tab=download>

Thermal Intelligence from Space | Satleo Labs. (n.d.). Retrieved August 14, 2026, from <https://www.satleolabs.com/>

Varanasi Heat Action Plan - Mahila Housing Trust. (n.d.). Retrieved August 14, 2026, from <https://www.mahilahousingtrust.org/knowledgehub/varanasi-heat-action-plan/>

VizHub - GBD Results. (n.d.). Retrieved August 13, 2026, from <https://vizhub.healthdata.org/gbd-results/>

WHO guidance for climate resilient and environmentally sustainable health care facilities. (n.d.). Retrieved August 14, 2026, from <https://www.who.int/publications/i/item/9789240012226>

Yi, L., Xu, R., Yuan, X., Ren, Z., Song, H., Lai, H., Sun, Z., Deng, H., Yang, B., & Yu, D. (2024). Heat stress enhances the occurrence of erythromycin resistance of *Enterococcus* isolates in mice feces. *Journal of Thermal Biology*, 120, 103786. <https://doi.org/10.1016/J.JTHERBIO.2024.103786>

Zhang, J. D., Cheng, X. F., Min, S. H., Guo, R. Q., Wang, R. N., He, Y. T., Zhang, Y. L., & Li, B. (2024). Burden of non-communicable diseases attributable to high temperature in a changing climate from 1990 to 2019: a global analysis. *BMC Public Health*, 24(1). <https://doi.org/10.1186/s12889-024-19947-z>



www.indiahealthfund.org

3rd Floor, Elphinstone Building, Veer Nariman Road,
Horniman Circle, Fort, Mumbai 400001
contact@indiahealthfund.org