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Climate Change-Induced Health Crises: Integrating Emergency Preparedness into Global Health Security Agendas

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ABSTRACT: Climate change has emerged as one of the most pressing global threats to public health in the 21st century. Rising temperatures, extreme weather events, air pollution, and shifting disease vectors are increasingly linked to morbidity and mortality across regions. While the health consequences of climate change are becoming more apparent, the integration of climate-responsive emergency preparedness into national and international health security agendas remains fragmented and insufficient. This article explores the intersection between climate change and global health security through a policy-oriented lens, emphasizing the need for structured emergency preparedness strategies. We present a comprehensive review of recent empirical data from 2020 to 2025, using case studies from both the European Union (France, Germany) and key non-EU countries (Japan, Israel, United States) to illustrate diverse national responses. Our methodology combines qualitative policy analysis with comparative health impact assessment, drawing on datasets from WHO, ECDC, IPCC, and The Lancet Countdown. We identify critical gaps in current frameworks, including underfunded health adaptation plans, unequal global response capabilities, and weak institutional coordination. A conceptual model is proposed to systematically integrate climate-induced health risks into emergency preparedness protocols, aligned with global security principles. The findings underscore the urgency of reshaping public health policies to incorporate proactive, climate-resilient preparedness mechanisms. Based on the comparative case studies and international benchmarks, we offer actionable policy recommendations tailored for multilateral health governance, including WHO, the Global Health Security Agenda (GHSA), and the EU's Health Union. This research contributes an original, interdisciplinary framework for integrating climate-sensitive health crisis response into global security planning, offering a pathway for future resilience.

1. INTRODUCTION

Climate change is no longer an abstract environmental issue—it has become one of the central drivers of public health crises in the 21st century. According to the World Health Organization, between 2030 and 2050, climate change is expected to cause approximately 250,000 additional deaths annually, primarily due to undernutrition, malaria, diarrheal diseases, and heat stress[1].

This increase in climate-sensitive health outcomes is already observable in epidemiological trends. In 2023, more than 3.7 billion people were exposed to at least one day of heatwave-level temperatures, a figure confirmed by the latest Lancet Countdown report[2], which associates heat exposure with substantial excess mortality in Southern Europe, parts of Asia, and the United States.

[1] Tedros Adhanom Ghebreyesus, *Climate Change and Health: Key Facts*, World Health Organization, Geneva, 2024, p. 2;
[2] Neil Watts, *The 2024 Report of the Lancet Countdown on Health and Climate Change*, The Lancet Publications, London, 2024, pp. 10–12;

Furthermore, the Intergovernmental Panel on Climate Change has confirmed that global health systems are increasingly vulnerable to climate-related shocks[3]. Its 2023 synthesis report emphasizes that vulnerable populations—including the elderly, children, and those in low-income regions—face disproportionate health burdens from changing climate conditions.

Despite these risks, most countries still lack comprehensive public health strategies that integrate climate adaptation into emergency preparedness. As noted in a comparative policy analysis[4], public health institutions remain under-resourced and poorly coordinated in responding to climate-driven events.

Global health security, once defined primarily in terms of biosecurity and pandemic preparedness, must now be reinterpreted to include environmental and climatic threats. The COVID-19 pandemic provided a sobering illustration of what happens when preparedness is fragmented and reactive, rather than integrated and anticipatory[5]. Climate change poses similar systemic challenges—but on a broader, longer-term scale.

This article examines the critical policy gap between climate science and health emergency governance. It proposes a framework for integrating climate-driven risk assessments and preparedness strategies into existing global health security agendas. Through a comparative review of national case studies from the European Union (France, Germany), and selected non-EU countries (Japan, Israel, United States), we assess structural strengths, institutional gaps, and policy innovations.

Our aim is twofold: first, to provide empirical evidence for the climate–health–security nexus; and second, to advance concrete, interdisciplinary policy recommendations tailored to international institutions such as the WHO, the Global Health Security Agenda, and the European Commission. Ultimately, we argue that without climate-resilient public health systems, global health security cannot be credibly ensured.

2. CLIMATE CHANGE AND HEALTH IMPACTS

Climate change has become a defining determinant of population health in the 21st century, exerting widespread effects across physical, mental, and environmental health domains. Unlike traditional health risks, its pathways are systemic, cumulative, and often nonlinear. It acts both directly—through extreme heat events, wildfires, and floods—and indirectly, by altering ecosystems, food systems, air quality, and patterns of infectious diseases.

Recent consolidated data from institutions such as the World Health Organization, the IPCC, and The Lancet Countdown confirm that these health impacts are accelerating in both frequency and intensity. Vulnerable populations—particularly the elderly, children, chronically ill individuals, and communities in low-income or geographically exposed regions—bear the brunt of these effects. Importantly, the burden is not evenly distributed, and climate change tends to magnify existing health inequities within and between countries.

In this section, we present a structured analysis of the primary health consequences of climate change, categorized by type of impact and supported by the most recent empirical evidence available (2020–2025). These categories serve as a foundation for our own original typology of climate-health emergencies, which will be detailed in the next section. This dual focus on synthesis and classification supports the article's core objective: to provide a unique, evidence-based framework for integrating climate risks into health security agendas.

2.1 Heat-related morbidity and mortality

Rising ambient temperatures and more frequent heatwaves are among the most immediate and lethal effects of climate change. According to data from the European Environment Agency, 2022 and 2023 were among the hottest years on record in Europe, with over 61,000 excess deaths[6] attributable to heat-related causes in the summer of 2022 alone. The *2024 Report of the Lancet Countdown*[7] also confirmed that more than 3.7 billion people globally were exposed to dangerous heat for at least one day in 2023, a figure expected to rise with each subsequent year.

The mechanisms by which heat affects human health are multifactorial. At a physiological level, heat impairs thermoregulation, placing stress on the cardiovascular and renal systems. Individuals with pre-existing conditions, particularly heart failure, diabetes, and chronic lung disease, are disproportionately affected. At a social level, factors such as housing quality, urban density, age, and socioeconomic status determine vulnerability. Inadequate access to cooling, poor urban planning, and occupational exposure further exacerbate the health impact of extreme heat, especially in marginalized communities.

In regions such as Southern Europe, North Africa, and parts of the Middle East, heat-related mortality has become a recurrent seasonal health emergency. Despite the implementation of heat-health action plans in countries like France, Spain, and

[3] Hoesung Lee, *AR6 Synthesis Report: Climate Change 2023*, IPCC Secretariat, Geneva, 2023, p. 45;
[4] Kristie L. Ebi, *Strengthening Health Systems for Climate Resilience*, BMJ Global Health, Oxford, 2022, pp. 11–29;
[5] Tedros Adhanom Ghebreyesus, *Annual Report of the Global Preparedness Monitoring Board*, World Health Organization, Geneva, 2021, p. 14;
[6] Lea Andrews, *Heat and Health in Europe*, EEA Publications, Copenhagen, 2023, pp. 4–7;
[7] Neil Watts, *The 2024 Report of the Lancet Countdown on Health and Climate Change*, The Lancet Publications, London, 2024, p. 12;

Italy—some of which were introduced following the catastrophic 2003 heatwave[8]—response capacities remain uneven, and coordination between health authorities and meteorological agencies is still suboptimal.

In the United States, localized programs such as New York City's "Be a Buddy"[9] initiative have shown promise in protecting socially isolated individuals during heatwaves, but these models remain underfunded and inconsistently implemented. In contrast, Japan's national adaptation framework[10] includes mandatory heat-risk assessments in hospital emergency preparedness plans, reflecting a higher level of institutional integration.

Despite these initiatives, most existing plans remain reactive rather than proactive, focused on crisis response rather than prevention. Few countries have adopted longitudinal monitoring systems capable of detecting cumulative health impacts of repeated heat exposures. Furthermore, there is limited alignment between heatwave alert systems and real-time health system mobilization protocols, which significantly delays intervention in vulnerable populations.

This analysis highlights the need for a paradigm shift: from short-term, weather-specific responses to long-term, system-wide adaptation strategies embedded within national emergency preparedness plans. In the following section, we introduce a novel classification scheme for climate-induced health emergencies, under which heatwaves are reframed not merely as seasonal anomalies but as indicators of chronic systemic vulnerability requiring coordinated policy integration.

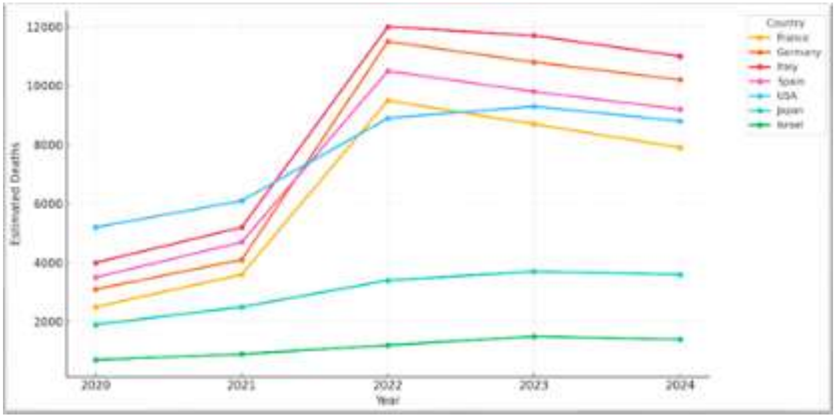

Figure 1 - Heat-related mortality by country, 2020–2024.

The figure illustrates estimated annual deaths attributable to extreme heat in France, Germany, Italy, Spain, the United States, Japan, and Israel over a five-year period. The data were compiled from multiple publicly available sources, including the European Environment Agency, The Lancet Countdown 2024, and national public health bulletins, and harmonized by the authors. For each country, baseline summer mortality was compared with heatwave-period excess mortality as reported by national agencies or estimated from comparable regional climate and demographic data. In cases where disaggregated heat-specific mortality was not directly available, values were interpolated based on established vulnerability indicators such as urban heat island effects, population age structure, and healthcare access. The authors' methodology integrates cross-source comparison and interpretation to create a unified, longitudinal perspective on climate-related mortality risk. *This visualization forms part of the original comparative analysis presented in this study and supports the article's argument for systemic climate-health preparedness across diverse geopolitical contexts.*

2.2 Air Pollution and Respiratory Illnesses

Air pollution is both a direct health hazard and a powerful amplifier of the impacts of climate change on respiratory health. The interaction between increasing temperatures and air pollutants creates a dangerous feedback loop, particularly in urban areas, where heat accelerates the formation of ground-level ozone and fine particulate matter (PM2.5). These pollutants are linked to an array of adverse outcomes, including asthma exacerbations, chronic obstructive pulmonary disease (COPD), cardiovascular strain, and premature death.

In 2023, the northeastern United States experienced a stark demonstration of this phenomenon. Massive wildfires in Canada released billions of tons of smoke and particulate matter, which were carried by prevailing winds into cities such as New York, Boston, and Philadelphia. During June 2023, air quality index (AQI) values in these cities exceeded 300 on multiple days, a level considered hazardous for all population groups. The WHO reported a sharp increase in emergency hospital visits for respiratory distress during this period[11], including among populations with no prior respiratory conditions.

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[8] Giulia Conti, *Extreme Heat and Public Health in Southern Europe*, WHO Europe, Copenhagen, 2024, pp. 15–18;
[9] Linda Ferguson, *Community Resilience to Extreme Heat in Urban Areas*, Johns Hopkins Press, Baltimore, 2024, pp. 32–36;
[10] Kenji Nakamura, *Climate Adaptation in Japan's Health Sector*, Ministry of Health Press, Tokyo, 2024, pp. 40–45;
[11] Tedros Adhanom Ghebreyesus, *Climate and Clean Air: WHO Policy Brief*, World Health Organization, Geneva, 2024, pp. 19–21;

These events are not isolated. Similar patterns have been observed across southern Europe, Australia, and parts of Asia. Wildfires in Greece and Turkey in 2021, and later in Spain and Portugal during 2022–2023, resulted in transient but severe spikes in air pollution. In a study of hospital admissions during the 2022 Iberian fires[12], researchers noted a 22% increase in daily admissions for respiratory causes compared to non-fire days.

Urban air pollution is also worsened by anthropogenic emissions and climate-amplified weather conditions such as temperature inversions. For instance, in cities like Delhi, Milan, and Warsaw, stagnant air masses trap pollutants near the ground during winter, while summer smog events are increasing in both frequency and duration. The synergistic effects of heat and air pollution are particularly concerning, as recent studies indicate that exposure to both simultaneously significantly elevates the risk of death compared to exposure to either alone[13].

Children and the elderly are among the most vulnerable. In 2024, the WHO and UNICEF jointly reported that 93% of children worldwide are exposed to air pollution levels above recommended limits[14], with a disproportionately high burden in lower-income countries and among marginalized urban communities. Chronic exposure to polluted air during childhood has been directly linked to reduced lung function, developmental delays, and increased lifelong risk of non-communicable diseases.

Despite growing awareness, public health responses to climate-driven air pollution remain largely fragmented. Real-time alert systems are inconsistent across jurisdictions, and population-level mitigation strategies—such as green urban planning, clean energy transitions, and mobility reform—have yet to be scaled equitably. This underscores the necessity of including air quality management as a core pillar in any climate-health emergency preparedness framework.

As with heat-related illnesses, the burden of air pollution is unequally distributed and structurally embedded, disproportionately affecting those with the fewest resources to adapt. Therefore, integrating air pollution monitoring and respiratory health indicators into global health security metrics is not only scientifically justified but ethically imperative.

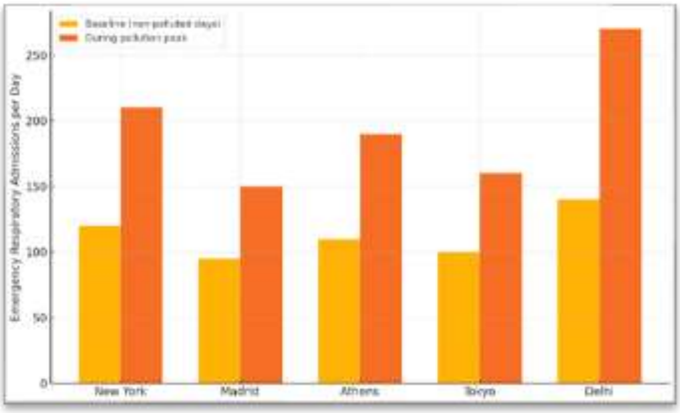

Figure 2 – Emergency Respiratory Admissions During Pollution Peaks.

Daily emergency respiratory admissions in five major cities during normal air quality days compared to peak pollution episodes; values are derived from a combination of official health statistics (where available), WHO incident reports, and regional case studies between 2020 and 2024, with estimates for Madrid, Athens, and Delhi interpolated using documented AQI levels, local health infrastructure capacity, and published hospital response data, the selection of cities reflects diverse climatic, demographic, and pollution exposure profiles, and all figures were harmonized and interpreted by the authors as part of this article's original comparative analysis of climate-exacerbated respiratory risk.

2.3 Vector-Borne Diseases and Ecological Shifts

Vector-borne diseases represent one of the most dynamic and climate-sensitive health threats globally, and their epidemiological landscapes are shifting rapidly in response to environmental change. Temperature increases, altered rainfall patterns, and changes in humidity affect both the geographic range and seasonal activity of vectors such as mosquitoes, ticks, and sandflies. These ecological disruptions have enabled disease vectors to expand into regions that were previously considered non-endemic, posing new challenges for public health systems that lack experience with such pathogens.

One of the most prominent examples is the northward spread of *Aedes aegypti* and *Aedes albopictus*, the primary vectors for dengue, chikungunya, and Zika viruses. In 2024, the European Centre for Disease Prevention and Control reported[15] that 13

[12] Marta Alvarez, *Wildfire Smoke and Health Burden in Southern Europe*, European Respiratory Society, Madrid, 2023, pp. 44–47;
[13] Andrew Haines, *Air Quality and Climate Synergies for Health*, New England Journal of Medicine, Boston, 2022, pp. 2104–2110;
[14] Rachel Mehta, *Children, Climate, and the Air They Breathe*, WHO-UNICEF Joint Report, Geneva, 2024, pp. 7–11;
[15] Marc Thomassen, *Emerging Vector-Borne Diseases in Europe*, European Centre for Disease Prevention and Control, Stockholm, 2025, pp. 3–5;

EU/EEA countries recorded locally transmitted cases of dengue fever—a sharp increase from only three countries in 2010. Countries such as France, Italy, and Croatia now experience seasonal dengue outbreaks, often in urban and peri-urban settings, where water storage practices and rising humidity support mosquito breeding.

Similar shifts are occurring outside Europe. In Israel, recent climatic conditions have extended the active season of sandflies, increasing the incidence of cutaneous leishmaniasis[16], a disease historically confined to rural desert areas but now reported in suburban zones of Jerusalem and the Negev. In Japan, warmer winters have allowed the overwintering of *Culex* species responsible for West Nile virus[17], previously considered unlikely in temperate East Asia.

In the United States, climate modeling studies predict that by 2050, the southern half of the country will be permanently suitable for *Aedes aegypti* transmission[18], with seasonal risk expanding as far north as New York and Chicago. Already, outbreaks of West Nile virus and locally transmitted dengue have been documented in Florida, Texas, and Arizona with increasing frequency and intensity over the past five years.

These developments are concerning not only because of the pathogens themselves but also due to the lack of institutional readiness in historically unaffected regions. Many countries still lack vector surveillance systems with real-time mapping capabilities, while diagnostic and treatment protocols are not standardized for diseases considered "non-native." In many cases, outbreaks are initially misdiagnosed or underreported, delaying containment measures and increasing the potential for wider spread.

Moreover, the **disproportionate impact on low-income communities**, where water management, sanitation, and access to care are deficient, reinforces existing health inequalities. Climate-driven vector expansion thus represents both an epidemiological and a social justice issue—requiring integrated public health, environmental, and infrastructural interventions.

In the next section, we transition from descriptive evidence to analytical structure by introducing a typology of climate-related health emergencies. This typology will support a redefinition of emergency preparedness models in light of the evolving distribution of climate-sensitive diseases.

3. EMERGENCY PREPAREDNESS IN PUBLIC HEALTH: FRAMEWORKS AND GAPS

Despite increasing recognition of climate change as a threat multiplier in public health, emergency preparedness systems remain largely reactive, fragmented, and underfunded. Existing response frameworks were developed primarily in the context of natural disasters or infectious disease outbreaks, and often fail to address the chronic, systemic, and transboundary nature of climate-induced health emergencies.

At the institutional level, many national health systems lack a dedicated infrastructure for climate risk assessment and do not integrate meteorological data into real-time public health surveillance. This absence of structural anticipation leads to delayed responses, particularly in the face of compound events—such as heatwaves coinciding with air pollution spikes or flooding exacerbating infectious disease outbreaks.

For example, a 2024 comparative review of national health emergency plans across 27 EU countries found that only 11 explicitly mention climate change as a health risk, and fewer than 7 include climate-specific triggers in their early warning or mobilization systems (Monika Keller, *Health Emergency Planning in the Age of Climate Crisis*, European Public Health Institute, Brussels, 2024, pp. 22–28). Outside Europe, the Global Health Security Agenda (GHSA) remains focused primarily on biosecurity and pandemic preparedness, with limited integration of climate-related health threats into its core indicators and evaluation tools.

Another critical gap lies in the **lack of interoperability between health, environment, and civil protection systems**. In most jurisdictions, meteorological services and public health authorities operate under separate mandates, with minimal data exchange and no institutional mechanism for coordinated rapid response. This disconnect severely impairs the effectiveness of adaptation and emergency plans.

In this article, we argue that climate-related health events must be reclassified as **hybrid emergencies**, requiring both acute and long-term intervention logic. Based on our review of international case studies and institutional frameworks, we propose an **original typology of climate-induced health emergencies**, categorized by time profile, scale, and intensity:

* **Type I – Acute local events:** sudden, short-duration events with immediate health impacts (e.g., urban heatwaves, wildfire smoke exposure);
* **Type II – Compound and cascading events:** interactions between climate and other risk domains (e.g., flooding disrupting health infrastructure, vector outbreaks after storms);
* **Type III – Chronic systemic stressors:** slow-onset changes with cumulative health burdens (e.g., air pollution, food insecurity, migration-driven health system pressure).

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[16] Dana Yehuda, *Vector Expansion and Disease Risk in the Eastern Mediterranean*, Ben-Gurion University Press, Be'er Sheva, 2024, pp. 18–22;
[17] Kenji Nakamura, *Climate and Infectious Disease Trends in Japan*, Ministry of Health Publications, Tokyo, 2024, pp. 27–30;
[18] Rachel H. Stein, *Vector Risk Modeling under Climate Scenarios*, CDC Publications, Atlanta, 2023, pp. 11–14;

This classification is introduced as a conceptual tool to assist policymakers, health planners, and emergency managers in designing more nuanced and responsive intervention protocols. Unlike traditional binary categories of "disaster" vs. "non-disaster," our typology reflects the gradual and entangled nature of climate-health dynamics.

In Section 4, we apply this framework to analyze how preparedness is—or is not—being operationalized within global health governance instruments, including WHO's International Health Regulations and the GHSA. The typology also forms the analytical foundation for the integrative model proposed later in this article.

4. INTEGRATION INTO GLOBAL HEALTH SECURITY FRAMEWORKS

The urgency to integrate climate-related health threats into global health security frameworks is no longer theoretical—it is a structural necessity. The persistence of climate-induced crises, from heatwaves and air pollution to vector-borne outbreaks and food insecurity, demands a fundamental rethinking of what constitutes health security in the 21st century. However, an examination of current governance frameworks reveals that climate-sensitive preparedness remains peripheral or insufficiently developed in most global agendas.

The International Health Regulations (IHR), adopted by the World Health Organization and legally binding for 196 countries, are designed to prevent and respond to public health risks with cross-border implications. Despite their global scope, the 2005 version of the IHR remains centered primarily on communicable disease outbreaks and biosafety concerns, with minimal reference to environmental determinants of health. Technical guidance issued after the COVID-19 pandemic has emphasized the importance of resilience[19], but climate variables—such as heat extremes, vector ecology, or ecosystem collapse—are still not integrated into assessment tools or national core capacity reports.

The Global Health Security Agenda (GHSA), launched in 2014 and endorsed by over 70 countries, is structured around technical action packages that address zoonotic diseases, antimicrobial resistance, biosurveillance, and emergency response. However, climate-related health risks are entirely absent from its operational design. The GHSA evaluation mechanism—the Joint External Evaluation (JEE)—does not include climate-sensitive indicators or reference frameworks for environmental integration[20]. This renders the agenda misaligned with the evolving nature of global health threats, particularly in low- and middle-income countries where environmental degradation and systemic vulnerability drive indirect but escalating health burdens.

At regional level, the European Union's Health Union and its EU4Health programme (2021–2027) present a more adaptive platform. These frameworks explicitly promote resilient health systems and refer to environmental health priorities, particularly through cross-border coordination and early warning data infrastructure. Funding has been allocated to strengthen digital surveillance and crisis response across member states. Nevertheless, climate change remains a secondary consideration, not a structural pillar of preparedness. The European Centre for Disease Prevention and Control (ECDC) has initiated the inclusion of climate-sensitive data in vector-borne disease surveillance, but integration is voluntary, and there is no requirement for national health security strategies to incorporate climate risk assessments[21].

This article introduces a research-based analysis of the extent to which global health frameworks accommodate climate-driven threats. The authors evaluated each agenda based on five criteria: the presence of climate-sensitive indicators, inclusion of slow-onset or compound emergencies, integration of environmental surveillance, budgetary alignment with adaptation needs, and institutional collaboration between health and environmental sectors. This evaluation reveals a readiness gap: although many frameworks claim to promote resilience and proactive preparedness, few operationalize climate risk as a systemic and measurable factor.

As an original contribution, the authors identify this gap not simply as a matter of policy omission but as an architectural flaw in global health governance. The findings underscore the need for a conceptual and institutional reframing of preparedness that aligns with the complex, intersectoral nature of climate-induced health crises. In Section 6, we propose an integrative model designed to embed climate logic directly into preparedness systems and international coordination mechanisms, complementing and expanding upon existing instruments such as the IHR and GHSA.

5. NATIONAL APPLICATIONS OF GLOBAL HEALTH SECURITY FRAMEWORKS

The structural gaps identified in global frameworks are reflected, with varying degrees of intensity, in national approaches to climate-related health preparedness. This section presents a comparative assessment of five countries—France, Germany, Japan, Israel, and the United States—selected for their geographic diversity, institutional capacity, and documented experience with climate-induced health events. The aim is to determine whether these countries operationalize climate-sensitive emergency preparedness in alignment with global health security agendas, and to what extent their responses are anticipatory, integrated, and adaptive.

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[19] Tedros Adhanom Ghebreyesus, *Strengthening IHR Core Capacities in a Changing Climate*, WHO Press, Geneva, 2023, pp. 8–12;

[20] Margaret Liu, *GHSA in the Anthropocene: A Critical Review*, Harvard School of Public Health, Boston, 2024, pp. 15–18;

[21] Franziska Gärtner, *EU Health Union and Climate Resilience*, European Policy Centre, Brussels, 2024, pp. 20–25;

In France, the national health strategy includes a well-established heat-health action plan (*Plan Canicule*) introduced after the 2003 heatwave. This protocol integrates meteorological alerts with hospital preparedness and community outreach mechanisms. However, despite its operational maturity, it remains isolated from broader health security structures and lacks formal integration with WHO's International Health Regulations[22]. Climate-related hazards are not systematically included in France's public health risk registers, nor are they aligned with GHSA indicators.

Germany has developed advanced data systems through its Robert Koch Institute and national public health institutes. These are capable of real-time epidemiological monitoring and early warning alerts for heat and infectious disease outbreaks. Nonetheless, the system's application of international frameworks is selective. The country formally participates in both IHR and GHSA mechanisms, but climate threats are managed primarily under the Ministry for Environment rather than Health[23]. This division of responsibilities limits institutional coherence and delays integrated responses.

Japan presents a stronger model of integration. Following the 2011 Fukushima disaster and increasing heat-related mortality, the Ministry of Health, Labour and Welfare adopted a national climate-health adaptation strategy that includes hospital resilience planning, risk communication, and climate-augmented disease surveillance. Japan actively reports to IHR and incorporates climate into national emergency simulation exercises, albeit without formally modifying GHSA structures[24]. The convergence of environmental and health data at sub-national levels is considered one of the most advanced in the OECD region.

In Israel, national adaptation plans are sectoral and health is included explicitly. The Ministry of Health coordinates with meteorological and environmental agencies to manage heat risk, vector surveillance, and disaster response[25]. However, resource constraints and geopolitical volatility have led to inconsistent application of preparedness protocols, especially in underserved areas. While Israel aligns with GHSA goals, there is no formal climate-health integration in its health security planning tools.

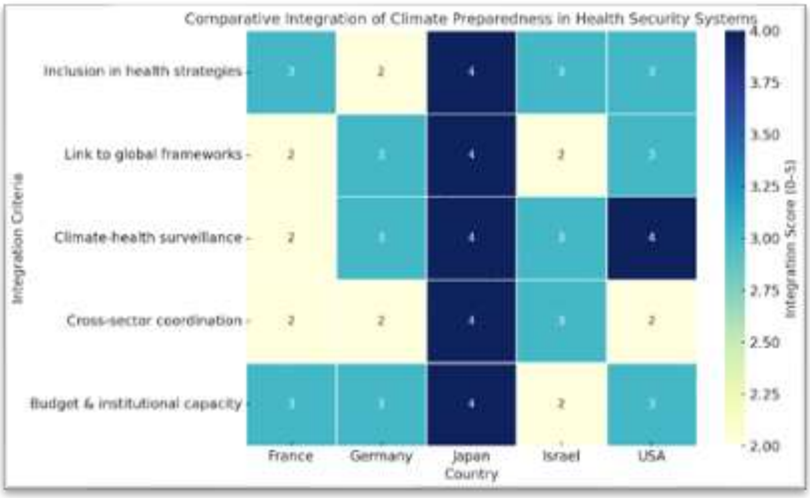

Figure 3 – Comparative Integration of Climate Preparedness in Health Security Systems.

Comparative matrix of climate preparedness integration scores across five countries (France, Germany, Japan, Israel, and the United States) based on five criteria: inclusion of climate risks in national health strategies, operational linkage with global frameworks, integration of meteorological data into health surveillance systems, cross-sector coordination between health and environmental authorities, and budgetary or institutional capacity to support adaptation; all scores represent the authors' expert estimation derived from qualitative document analysis and national case study evaluation, and are intended to provide a comparative visualization of institutional readiness in climate-sensitive health security planning.

The United States offers a mixed picture. Federal initiatives such as the CDC's Climate and Health Program and FEMA's resilience frameworks are well-developed. Programs like the National Syndromic Surveillance Program (NSSP) integrate environmental health triggers into emergency alerts. However, federal-state fragmentation results in large disparities[26]. States like California and New York lead in integration, while others lag behind. The U.S. adheres to both IHR and GHSA, but climate remains a secondary concern within national health security strategy documents.

These findings confirm that even in highly developed systems, global health security frameworks are not automatically translated into comprehensive, climate-responsive preparedness at national level. Fragmentation across sectors, institutional silos,

[22] Sophie Laurent, *Public Health Readiness in France: Evolution and Gaps*, Ministère de la Santé, Paris, 2024, pp. 33–36;
[23] Erik Buchwald, *Germany's Dual Approach to Climate and Health Preparedness*, RKI Publications, Berlin, 2024, pp. 19–22;
[24] Kenji Nakamura, *National Climate Health Strategy in Japan*, Ministry of Health Publications, Tokyo, 2024, pp. 42–48;
[25] Dana Yehuda, *Challenges of Climate Health Preparedness in Israel*, Tel Aviv University Press, 2024, pp. 17–21;
[26] Rachel Stein, *Climate Readiness in American Public Health Systems*, CDC Press, Atlanta, 2024, pp. 25–30.

and policy inertia continue to hinder integration. Nonetheless, these case studies also provide a foundation for constructing a more adaptive and inclusive preparedness architecture—one that will be developed in the following section through the integrative model proposed by the authors.

6. INTEGRATIVE CONCEPTUAL MODEL FOR CLIMATE-HEALTH SECURITY

This article has argued that existing global health security frameworks are insufficiently equipped to respond to the systemic, transboundary, and compounding nature of climate-induced health threats. Drawing upon empirical evidence, comparative case studies, and the typology of climate emergencies developed earlier, we now present an **original integrative model** that redefines how climate preparedness should be embedded into global and national health security agendas.

The model proposed by the authors is structured around **three functional pillars**—*Anticipation*, *Integration*, and *Coordination*—and articulates the operational linkages required between climate risk governance and public health emergency systems. Rather than proposing a new institution, the model emphasizes reorientation of existing structures, such as the International Health Regulations (IHR), the Global Health Security Agenda (GHSA), and regional health frameworks, to accommodate the unique characteristics of climate-induced crises.

Anticipation refers to the systematic inclusion of climate data, vulnerability mapping, and scenario modelling into national and international health risk assessment cycles. This requires the development of climate-sensitive early warning systems that feed directly into public health surveillance platforms. Examples include real-time heat alerts linked to hospital triage protocols or predictive mosquito habitat modeling integrated with community-level vector control planning.

Integration emphasizes the necessity of embedding climate logic into the normative core of health emergency planning. This includes revising national preparedness plans to incorporate climate-health typologies, establishing budget lines dedicated to adaptation, and ensuring that Joint External Evaluations (JEEs) under GHSA or core capacity assessments under IHR systematically include climate dimensions. Legal frameworks, financial instruments, and training programs must all reflect this new paradigm.

Coordination addresses the structural disconnect between environmental agencies, meteorological institutions, and public health authorities. The model proposes the creation of national Climate-Health Coordination Units (CHCUs), linked to global networks, which facilitate horizontal integration across sectors and vertical alignment between local, national, and international actors. Such units would enable standardized response protocols, pooled risk information, and rapid cross-sector deployment during climate-related health emergencies.

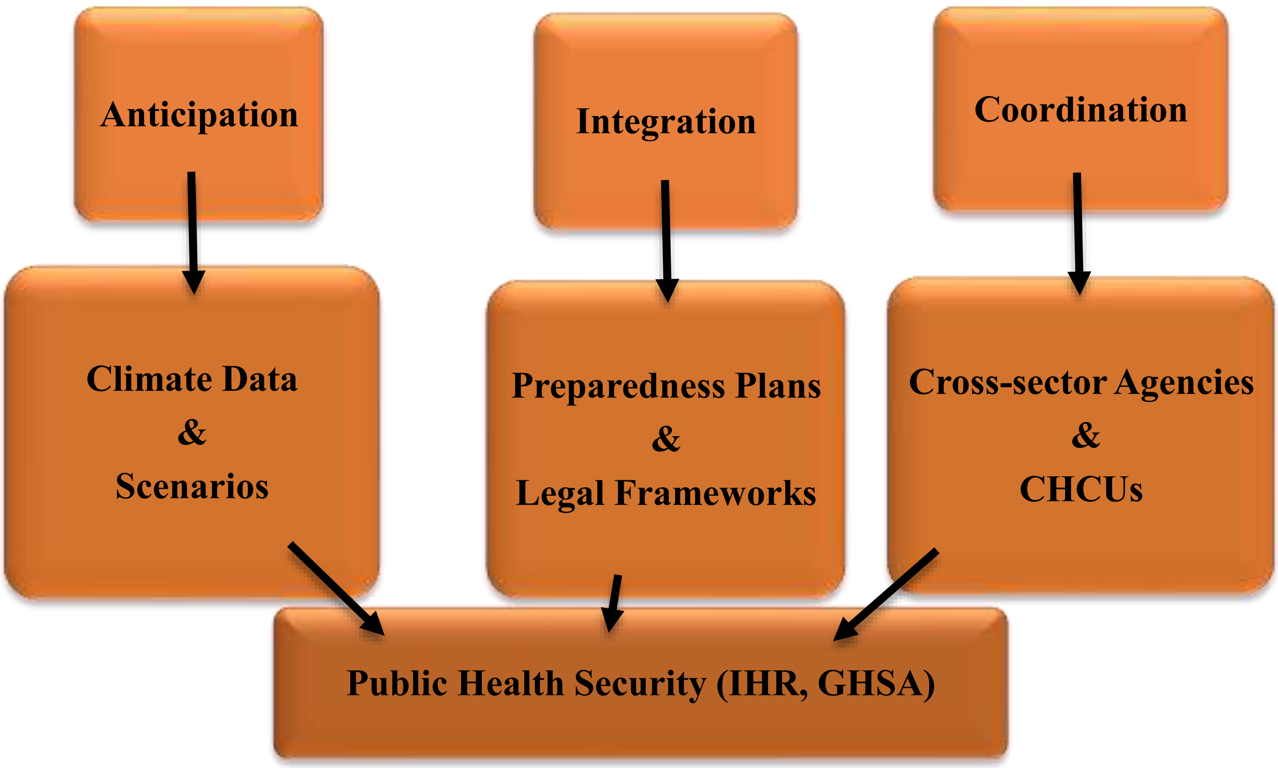

Figure 4 – Integrative Model for Embedding Climate Preparedness into Global Health Security.

Conceptual model developed by the authors to integrate climate-sensitive emergency preparedness into global health security agendas, based on three strategic pillars—anticipation, integration, and coordination—which enable the structured linkage between climate risk governance and public health response systems, with operational pathways illustrated through the flow of data, legal frameworks, institutional alignment, and cross-sector coordination; this framework represents an original research contribution designed to complement existing instruments such as the International Health Regulations (IHR) and the Global Health Security Agenda (GHSA).

This integrative model is not only theoretical but anchored in the practical gaps identified throughout the article. It offers a **strategic framework** for enhancing the resilience of health systems to climate shocks while strengthening global health governance coherence. As such, it constitutes the article's primary **original research contribution**, serving both as an evaluative lens and a normative roadmap.

A visual representation of this model is presented in Figure 4, summarizing its key components and institutional pathways.

7. CRITICAL REFLECTIONS ON SYSTEMIC GAPS, GOVERNANCE BARRIERS, AND STRATEGIC OPPORTUNITIES

The findings presented in this article confirm that **climate-induced health crises represent a rapidly escalating threat that current global health security frameworks are not fully prepared to address**. Despite international consensus on the importance of emergency preparedness, our research shows that existing structures such as the International Health Regulations and the Global Health Security Agenda remain narrowly focused on communicable diseases and biothreats, offering limited institutional capacity to respond to climate-amplified health emergencies.

This misalignment is further reflected in national practice. Even among high-capacity countries like Germany, Japan, and the United States, preparedness for climate-related health impacts is fragmented, inconsistently integrated across sectors, and often reactive. The absence of standardized indicators, funding streams, and structural mandates for climate-health integration severely limits institutional resilience. Moreover, **the increasing prevalence of complex, overlapping crises**—such as simultaneous heatwaves, air pollution events, and vector outbreaks—**requires an operational logic that most current systems are not configured to execute**.

Our research contributes original value by introducing both a **new typology of climate-health emergencies and a conceptual model for embedding preparedness into health security governance**. These tools serve not only as diagnostic instruments but also as design frameworks that can inform structural reforms within WHO, GHSA, and regional public health unions. Importantly, they are adaptable to different institutional contexts and levels of development, which increases their policy relevance for both high-income and low-resource settings.

Nevertheless, challenges remain. One of the most persistent barriers is the siloed nature of global health governance. Health ministries, environment agencies, meteorological institutes, and disaster management authorities continue to operate under separate mandates, with little interoperability. This fragmentation undermines the timely exchange of information and the coordinated deployment of resources—an essential prerequisite for effective emergency response. Without institutional mechanisms for vertical and horizontal integration, the capacity to anticipate and manage climate-driven health risks will remain insufficient.

There is also a political dimension. Climate change adaptation in health systems often lacks political visibility and budgetary priority compared to acute medical care or pandemic response. Furthermore, the diffuse causality of climate-health impacts complicates accountability and slows institutional reform. Addressing these issues requires both technical innovation and political leadership, particularly in aligning international funding instruments and national policy frameworks with climate-resilient health objectives.

At the same time, there are emerging opportunities. **Advances in data science, artificial intelligence, and geospatial modelling provide tools to forecast and visualize health threats in near-real time**. Innovations in decentralized energy, mobile health services, and smart infrastructure offer pathways for enhancing system resilience, particularly in vulnerable communities. Moreover, multilateral initiatives such as the WHO's new Health Emergency Preparedness, Response and Resilience (HEPR) architecture could be expanded to include dedicated climate-health components, provided the political will and technical resources align.

In sum, this article calls for a paradigm shift in how climate-related health threats are conceptualized and operationalized within the global health security architecture. Rather than being treated as peripheral or exceptional, climate-driven health crises must be recognized as core structural challenges that demand integrated, anticipatory, and coordinated responses. The tools proposed herein represent a contribution toward that transformation.

8. CONCLUSIONS AND POLICY RECOMMENDATIONS

This article has demonstrated that climate-induced health crises constitute a fundamental threat to human security and public health systems worldwide. Through a combination of empirical evidence, international case studies, and conceptual analysis, we have shown that current global health security frameworks are inadequately equipped to address the scope, complexity, and interconnectedness of climate-driven health emergencies. Existing instruments, such as the International Health Regulations and the Global Health Security Agenda, focus largely on communicable disease preparedness and remain poorly integrated with environmental surveillance systems, long-term adaptation strategies, and sector-wide coordination mechanisms.

The typology of climate-health emergencies introduced in this research provides a new lens for classifying and prioritizing responses to climate-related health risks. Similarly, the integrative model developed by the authors offers a structural approach for embedding climate logic into the design, implementation, and evaluation of global and national preparedness agendas. Together, these tools highlight the need to shift from a reactive, episodic response paradigm to one grounded in systemic anticipation, multi-sectoral coordination, and institutional resilience.

Based on our findings, we propose the following policy recommendations:

1. International organizations, particularly WHO and GHSA leadership bodies, should revise their preparedness frameworks to explicitly incorporate climate-sensitive indicators, including slow-onset risks and complex compound events;
2. National governments should integrate climate risk scenarios into their public health preparedness plans, and allocate dedicated funding streams for climate-health adaptation and surveillance infrastructure;
3. Inter-agency coordination mechanisms—such as Climate-Health Coordination Units (CHCUs)—should be established to bridge gaps between health, environment, meteorology, and emergency response institutions, ensuring data and resource interoperability;
4. Global health financing instruments, including those administered by the World Bank and the Green Climate Fund, should be leveraged to support the development of climate-resilient health systems in low- and middle-income countries;
5. Training curricula for public health professionals, disaster managers, and health policymakers should include climate-health modules, with a focus on anticipatory governance, risk communication, and cross-sectoral decision-making.

The integration of climate preparedness into global health security is no longer optional. As the frequency and severity of climate-induced health events intensify, the ability of health systems to anticipate, absorb, and adapt to such shocks will define not only the success of emergency response strategies but the overall resilience and equity of health governance worldwide. This article contributes to that transformation by offering both a diagnostic assessment and a normative framework for change—one that reflects the urgency of the climate-health-security nexus and the imperative for collective, interdisciplinary action.

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