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Climate Change and Human Health — A Research Agenda for Action

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The health effects of climate change are profound and multifaceted. Extreme weather events such as heat waves, hurricanes, wildfires, and floods cause injury, death, and a growing burden of mental health conditions. Shifting environmental conditions drive the spread of vectorborne diseases, worsen air quality, and threaten food and water security, while disrupting sanitation systems and exacerbating malnutrition. These effects ripple across communities, disproportionately burdening high-risk populations, straining public health systems, and deepening existing inequities. They are further shaped by social determinants, including economic status, access to health care, and preexisting conditions.[1]

A growing body of research has documented these effects, with successive reports from the Intergovernmental Panel on Climate Change and the World Health Organization underscoring the urgency of addressing climate-related health threats. However, substantial knowledge gaps remain. Research on climate-related health effects is disproportionately concentrated in high-income countries, which leaves substantial uncertainty about effects in low- and middle-income countries, where climate vulnerabilities are often greatest. Furthermore, although studies of air pollution, heat stress, and extreme weather events are abundant, other critical issues — such as the mental health consequences of climate change, under-

nutrition resulting from food-system disruptions, and climate-induced displacement and migration — remain understudied.[2]

Strategies for mitigation and adaptation, including transitions to clean energy, the development of more-resilient health care systems, and nature-based solutions, offer critical co-benefits for health. Yet many dimensions of climate-related health risks remain underexplored. Climate-driven migration, maternal and child health, cross-generational effects, mental health, sex disparities, and the intersection of social vulnerabilities are particularly underrepresented in research.

Recognizing the urgent need to advance understanding, inform policy and practice, and protect human health in a changing climate, the National Academy of Medicine (NAM), in collaboration with Kaiser Permanente, has developed a *Research Agenda to Protect Human Health and Build Resilience in the Face of a Changing Climate*.[3] This research agenda is designed to fill critical knowledge gaps, synthesize existing evidence, and make information more accessible and digestible for decision makers. Critically, the research agenda aims to advance understanding, guide policy and practice, and ultimately protect and improve human health in the face of a changing climate.

This agenda identifies four key domains, which emphasize the need for interdisciplinary, equity-centered research to inform policy and

practice. By prioritizing rigorous study of climate–health interactions, investing in research infrastructure, and improving knowledge synthesis for decision makers, health systems and communities can better prepare to respond to the evolving challenges posed by climate change.

THE UNEVEN LANDSCAPE OF CLIMATE–HEALTH RESEARCH

Scientific evidence linking climate change to adverse health outcomes has increased substantially in the past decade. However, the distribution of research remains uneven. A systematic review found that over 80% of studies on climate and health originate from North America, Europe, and Australia, although low- and middle-income countries face disproportionate climate vulnerabilities.[4] This imbalance hinders global preparedness, since the regions most affected by climate change remain understudied and underfunded.

Furthermore, research on health outcomes related to climate change has focused primarily on heat-related mortality, air pollution, and extreme weather events. Although these areas are important, they do not fully capture the scope of climate-related health risks. Key understudied areas include the mental health effects of extreme weather events and displacement, the long-term nutritional consequences of climate-driven agricultural losses, the specific risks that climate change poses to maternal and child health, and the complex dynamics of climate-related migration and strain on public health systems. In addition, health inequities — exacerbated by climate change — are insufficiently documented, which limits the ability to design policies that effectively protect vulnerable populations.

Addressing these challenges will require bold new approaches. Data gaps, particularly with respect to vulnerable communities, hinder our ability to design equitable policies. The involvement of the private sector must be encouraged, along with building capacity for research, engaging in implementation science, and developing infrastructure. Funding mechanisms to support this work must also be reevaluated. Creating a truly meaningful research agenda demands input from across the health sector, affected communities, policymakers, and private funders. It must be an international, multidisciplinary, and community effort with equity at its core.

DATA GAPS AND LIMITATIONS IN RESEARCH INFRASTRUCTURE

One of the most important barriers to advancing climate–health research is the lack of available data. Many existing models fail to account for sex, ethnic group, race, and socioeconomic disparities, which limits our ability to track the disproportionate effects of climate change on vulnerable populations.

In addition, formal detection and attribution research, which links specific health outcomes to climate change, requires longitudinal data sets that span multiple decades. However, such data are often unavailable, and many low- and middle-income countries lack the data infrastructure necessary to quantify the full extent of climate-related health effects.

Beyond data gaps, funding inequities further hinder progress. Research on climate–health interactions remains severely underfunded relative to the importance of such research for public health. A recent analysis found that global funding for infectious disease research dwarfs investments in studies of climate and health, despite evidence that climate change exacerbates infectious disease transmission.[5] To accelerate progress, strategic investments in climate–health surveillance, data sharing, and research capacity are essential.

A RESEARCH ROAD MAP FOR CLIMATE AND HEALTH

The research agenda of NAM is the result of a multiphase, collaborative process designed to ensure inclusivity and relevance across diverse stakeholders. Recognizing the complexity of climate–health interactions, NAM engaged researchers, health care professionals, policymakers, community leaders, and persons with lived experience to identify priority areas for investigation. This process included informational interviews, literature reviews, and collaboration — including a public workshop — with experts across disciplines spanning environmental health, epidemiology, public health, and health equity. Community representatives, including those from rural and Indigenous populations, contributed essential perspectives on climate vulnerabilities to ensure that the research agenda reflects both scientific rigor and real-world experiences.

Table 1. Overarching Domains and Research Gaps.

Domain	Topics
Domain 1: Climate effects on health and related economic outcomes in the United States	Heat-related illness and mortality Health effects of extreme weather events (e.g., hurricanes, floods, and droughts) Waterborne diseases Air quality and climate health Vectorborne diseases (e.g., malaria, dengue, and Lyme disease) Food security and nutrition Mental health and well-being Cross-generational effects of climate change on health High-risk populations living under conditions that increase vulnerability to the effects of climate change Climate-related migration and health challenges Gender-based perspectives in climate–health interactions
Domain 2: Strategies for climate–health resilience and infrastructure — adaptation, mitigation, and equity in action	Adaptation strategies for community resilience Technologies to mitigate the effects of climate change Vulnerable populations and health equity Indigenous health and traditional knowledge Implementation science Collaboration and community engagement
Domain 3: Research and technology infrastructure and capacity building	Research infrastructure and ecosystem — interdisciplinary research and longitudinal studies Data gaps and capacity building in communities living at the intersection of conditions that increase vulnerability to the effects of climate change New technology, including artificial intelligence and tools for sensing, forecasting, and modeling climate change Development of a climate-savvy workforce Funding mechanisms
Domain 4: Policy and public communication, education, and engagement	Policy and governance for adaptation to changing climates and mitigation of the effects of climate change Public and policy engagement and education as a bidirectional process

Through this collaborative effort, NAM identified four key domains (Table 1) that require urgent research and investment. The first domain centers on understanding the direct and indirect effects of climate change on health and the related economic burden. Research is needed to quantify the health effects of extreme heat, air pollution, and climate-related disasters, as well as to examine the long-term consequences of exposure to these hazards. Such research should include investigating the biologic and environmental mechanisms underlying climate-related illnesses, determining how the insights gained can inform targeted interventions, and conducting longitudinal studies to assess chronic health effects over time. A One Health approach — which connects human, animal, environmental, and agricultural health, as well as biodiversity — is also essential for addressing the effects of climate change. For example, research that applies this approach can improve surveillance of zoonotic diseases, monitor cross-species health threats, and shed light on how climate change may influence antimicrobial resistance pathways. Eco-

nomic studies that assess the costs of climate-related illnesses, including mental health disorders and displacement-related stress, will be essential in guiding policymaking and resource allocation.

The second domain focuses on interweaving strategies for climate–health resilience and infrastructure. This approach includes research into strategies for adaptation and mitigation, with emphasis on interventions that provide direct health co-benefits. For example, strategies to mitigate urban heat — such as increasing green spaces — have been shown to lower heat-related mortality. Similarly, making a transition to cleaner energy sources not only reduces carbon emissions but also improves respiratory health outcomes. Priority areas include developing community-based strategies for adaptation, targeting vulnerable populations, addressing equity, and leveraging Indigenous knowledge. The resilience of health systems is another critical area of inquiry, particularly in assessing how the systems can prepare for climate disruptions while ensuring continued access to care for vulnerable populations.

The third domain highlights the need to en-

hance research and technology infrastructure. Strengthening capacity for climate–health research requires improved data collection and surveillance, particularly in regions where information is scarce. Research priorities include building interdisciplinary research ecosystems, enhancing surveillance and data collection systems, addressing data gaps in vulnerable communities, and developing a climate-savvy workforce. Advancements in artificial intelligence and machine learning offer opportunities to refine climate–health models and predict disease patterns, but research must focus on ensuring that these technologies, as well as associated sensors and modeling, are integrated with community-based data to ensure their relevance, with development of best practices for ethical use. Public–private partnerships will be crucial in scaling up climate–health research and leveraging resources across multiple sectors.

The fourth domain emphasizes the role of policy, public communication, education, and engagement in addressing climate-related health risks. The success of climate–health research depends not only on generating evidence but also on translating that evidence into actionable policies for adaptation and mitigation. Improving communication strategies that effectively convey climate-related health risks to policymakers, health care providers, and the public will be critical. Research in this domain should focus on improving policy frameworks to support coordination and implementation of climate–health strategies and identifying governance models that best include marginalized communities. In addition, efforts to enhance two-way communication, integrate public input into research, and foster mutual education are essential to empowering communities and improving the effectiveness of interventions. Addressing misinformation, strengthening science–policy partnerships, and ensuring that climate–health narratives are inclusive of diverse populations will be essential to mobilizing broad-based action.

CHARTING A PATH FORWARD

Advancing climate and health research requires a coordinated, interdisciplinary approach that fosters innovation, strengthens research infrastructure, and ensures long-term investment. The complexities of climate-driven health risks demand solutions that extend beyond traditional public health interventions and require collaboration across academia, government, and the private sector. There is a need to increase interest in climate and health research and innovation within the health sector, as well as across sectors, to promote a more convergence-oriented approach.

A critical step is catalyzing innovation and entrepreneurship to accelerate the development of scalable, cost-effective solutions for climate-related health challenges. Emerging technologies, such as artificial intelligence–driven early warning systems and climate forecasting models, can help predict disease outbreaks and extreme weather–related health emergencies. Investments in health care infrastructure that is "climate smart," including energy-efficient hospitals and mobile health clinics in regions that are particularly vulnerable to the effects of climate change, can enhance resilience and preparedness.

At the same time, sustaining a global scientific ecosystem for climate–health research is essential. Progress in this field depends not only on individual research projects but also on creating an infrastructure that supports long-term inquiry, data sharing, and interdisciplinary collaboration. Accelerating and catalyzing equitable, global interdisciplinary research collaboration and exchange and supporting capacity-building efforts in the most affected communities will be key to ensuring that no region is left behind. Establishing dedicated research centers, fostering mentorship opportunities for emerging climate–health researchers, and strengthening international research networks will help build the necessary capacity to address climate-driven health risks.

A fundamental challenge remains the long-term underfunding of climate and health research. In an era of constrained public budgets and shifting political priorities, meaningful increases in government funding are unrealistic. Instead, progress will depend on more-diverse funding strategies that leverage public–private partnerships, philanthropic contributions, and new financing mechanisms. The private sector has a growing financial stake in adaptation to climate change, given the economic risks associated with extreme weather events and supply-chain disruptions. Health systems, insurers, and biotechnology companies should be incentivized to invest in climate–health research, not only as a public good but also as a risk-mitigation strat-

egy. Governments, research institutions, and health systems can collaborate with the private sector to catalyze innovation and entrepreneurship. These partnerships can help mobilize additional funding and support the development of new investment mechanisms, including cross-agency initiatives and public–private funding models. Cross-sector partnerships can help bridge gaps where public funding falls short. In addition, innovative financial instruments — such as environmental-impact bonds and pooled research funds — and other financing models could provide new pathways for sustaining investment in this space. Rather than relying on fragmented, short-term grants, stakeholders across sectors must work toward integrated funding models that align with long-term research and implementation needs. Ensuring that climate–health research remains a priority will require creative funding strategies, strengthened cooperation, and a clear articulation of the economic benefits of action.

As climate change accelerates, its effects on public health will become increasingly severe. Addressing this crisis requires not only expanding the scientific understanding of climate–health interactions but also building the infrastructure, partnerships, and investment mechanisms needed to translate research into action. A comprehensive, equity-centered climate–health research agenda is essential to mitigating these risks and ensuring that health systems and communities are prepared for the challenges ahead.

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