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Climate Change and Respiratory Health: Opportunities to Contribute to Environmental Justice

An Official American Thoracic Society Workshop Report

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Abstract

Adverse environmental exposures worsened by our changing climate threaten respiratory health and exacerbate existing social inequities that further undermine environmental justice (EJ). EJ is the capacity of all people, regardless of sociodemographic characteristics, to minimize harmful exposures and live a healthy life. EJ is achieved through the development, implementation, and enforcement of environmental laws, regulations, and policies. In 2023, an American Thoracic Society workshop convened a group of 39 clinicians, researchers, community advocates, research program administrators, and health policy experts to characterize the respiratory health threats and EJ concerns arising from climate change. The workshop explored four main climate areas through a socioecological and EJ perspective: *1*) respiratory health risks, *2*) respiratory health impacts in low- and middle-income countries, *3*) climate mitigation and adaptation strategies, and *4*) priority research infrastructure needs. The workshop committee concluded that climate change can directly and indirectly impair respiratory health and that persistently excluded or marginalized communities (including those in low- and middle-income countries) are disproportionately impacted. These disproportionately impacted communities also lack hazard monitoring and resources to evaluate and advocate for mitigation of adverse environmental exposures. Future respiratory health research must inform mitigation strategies to reduce climate-related emissions from industry to net zero. Researchers, communities, and policymakers require training and support to meaningfully engage with systems-thinking research as well as policy solutions focused on mitigating and adapting to climate change. Finally, the workshop committee recommends a rapid transition away from fossil fuel dependence to a world that provides an equitable allocation of clean transportation options and renewable sources of energy production.

Keywords: respiratory health; climate change; environmental justice; social determinants of health; air pollution

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Introduction/Overview

Climate change will make the inequities and disparities worse, and widen that gap. That's why, this time, we have to get this right.—Dr. Robert Bullard, father of environmental justice (1)

Human activities have permanently altered the Earth's ecosystems and have led to increased concentrations of carbon dioxide (CO_2) and other greenhouse gases (GHGs) in the atmosphere, contributing to global temperature rise, sea level rise, and more extreme climate-sensitive events (e.g., wildfire, storms) (2). Worldwide, communities are experiencing adverse health effects as a result of climate change through multiple direct (e.g., heatwaves, increased storm frequency and intensity) and indirect (e.g., food and water insecurity, social instability, increases in air pollution) pathways (3). Specifically, with more frequent extremes in precipitation patterns and increasing temperatures, some regions will experience worsening desertification, leading to more frequent dust storms than in previous decades (4) and worsened droughtlike conditions by 2050 (5), whereas other regions will experience increased rain and flooding (6). The health impacts of climate change are far reaching, with a strong literature base of impact on respiratory diseases, cardiovascular diseases, infectious diseases, allergies, undernutrition (predominately in low-resource countries and low-income communities within high-resource countries), and physical injuries (7–9). In addition to these multisystem effects of climate change, we are at the nascent stages of understanding climate impacts on health issues, including cancer, mental health, endocrine disruption, and sleep deficiencies (10–13). Furthermore, the health impacts of climate change are unevenly distributed, with the highest risks experienced by economically, geographically, and/or socially marginalized communities, including minoritized races and ethnicities, older adults, women, young children, and people with disabilities (7, 14). To help address these inequities in exposure and health outcomes, we must focus on improving environmental justice (EJ).

Table 1. Glossaries of climate terms

Environmental Protection Agency Climate Glossary: https://19january2017snapshot.epa.gov/climatechange/glossary-climate-change-terms_.html
Climate Dictionary: United Nations Development Program. The Climate Dictionary: An everyday guide to climate change | Climate Promise (undp.org)

EJ Definitions

EJ is defined by the U.S. Environmental Protection Agency (EPA) as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies" (Table 1) (15). The communities that experience environmental injustice can be referred to as "environmental justice communities (EJCs)," "disproportionately affected communities," or "overburdened communities." The EPA defines "overburdened communities" as "minority, low-income, tribal and indigenous populations, or communities in the United States (US) that potentially experience disproportionate environmental harms and risks due to exposures or cumulative impacts or greater vulnerability to environmental hazards" (16). The language in our workshop report focused on describing external pressures on communities is compatible with the terminology of the U.S. government's Justice 40 initiative including the term "underserved-disadvantaged communities" (17).

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Artificial Intelligence Disclaimer: No artificial intelligence tools were used in writing this manuscript.

The essence of successfully incorporating EJ into society is captured by Professor Bunyan Bryant, Jr., a pioneer in the field: "EJ is supported by decent paying and safe jobs; quality schools and recreation; decent housing and adequate health-care; democratic decision-making and personal empowerment; and communities free of violence, drugs, and poverty" (18).

Methods

With the overall goals to define challenges related to the potential impact of climate change on respiratory health in EJ communities, describe evidence-based approaches for improving public health resilience to climate change related respiratory health threats, and review potential EJ-focused solutions to the identified challenges, we convened a workshop of several sessions from May through June 2023, which included academic pulmonary clinicians and researchers, community advocates, federal partners, and health policy experts (Table 2). This workshop served as an update of the 2012 American Thoracic Society (ATS) Climate Change Workshop by Pinkerton and colleagues (19) and expanded on that prior work by examining climate change from an EJ perspective and a focus on strategies for improvement. Four sessions used a "flipped classroom" (20, 21) model in which presentations were viewed independently by workshop members, who were then brought together for discussion and consensus building. The four sessions covered the following topics: *1*) defining the respiratory health effects of climate change through the lens of EJ, *2*) EJ and respiratory health issues impacting disproportionately affected low- and middle-income countries (LMICs), *3*) considering EJ and communities in climate change mitigation and adaptation strategies, and *4*) including EJ in priority research infrastructure needs to address climate change. This narrative review was constructed on the basis of the workshop sessions, offering a broad perspective on climate change and EJ, with a focus on complex topics that require further investigation and identification of gaps in knowledge.

The workshop chairs (Drs. Croft, Lee, Nordgren, and Thakur) and the writing committee identified the key topics of discussion and conclusions based on a review of meeting recordings, transcripts, and notes from the workshop sessions. The chairs and writing committee then drafted the initial report, which was subsequently shared with all workshop members for feedback on the content of this report. Of note, the link between the respiratory health benefit of mitigating climate change is primarily discussed in Introduction/Overview and EJ and Respiratory Health Issues Affecting LMICs, but because of the complexity of describing the strategies and potential solutions in EJ and Community Partnerships in Climate Mitigation and Adaptation and Including EJ in Policy and Priority Research Infrastructure Needs to Address Climate Change, addressing climate change is the main focus in these sections. Our workshop report includes discussion of areas of the response to climate change (e.g., EJ and renewable energy) that some may view as outside of our scope as clinicians, scientists, and community members (22). We assert that narrow views of professional "scope" have hindered the response to the climate crisis (in part by siloing responses) and that health professionals and scientists are essential in both leading and supporting advocacy efforts for equitable climate solutions.

Climate Change, Respiratory Health Effects, and Inequities

We must consider the direct and indirect impacts of climate change on respiratory health and the differential response to climate change across communities and social dynamics. There is clear documentation in the literature either directly or indirectly linking climate change to respiratory health conditions, including obstructive lung disease (asthma and chronic obstructive pulmonary disease [COPD]), respiratory infections, and upper airway disease (irritant and allergic rhinosinusitis) (23–25). Climate change augments exposure risk through a multitude of climate-sensitive exposures (considered exposures that can be worsened by climate change) (26). Climate change can directly worsen air quality through higher temperatures increasing ozone and volatile organic compound formation (both are respiratory irritants) and indirectly worsen air quality through increased fossil fuel use for heating and cooling demand during extreme temperatures (24, 27). Wildfire smoke is an example of a climate-sensitive exposure that results in an increase in the concentration and potentially the toxicity of the ambient air pollutant particulate matter $\leqslant$2.5 μm in aerodynamic diameter ($PM_{2.5}$) (28, 29). Increases in $PM_{2.5}$ concentrations are known to increase healthcare encounters for new or preexisting pulmonary conditions such as asthma (particularly children and elderly patients), COPD, pneumonia, and interstitial lung disease through inflammation and oxidative stress (30, 31). Extreme heat is another climate-sensitive exposure that also poses a unique risk to respiratory health, particularly for the young and elderly and those with underlying respiratory disease (32). Mechanistically, extreme heat from climate change can exacerbate asthma and some patients with COPD by directly triggering bronchospasm and cough through a cholinergic reflex (33), and is being studied as a potential synergistic risk factor with air pollution in threatening respiratory health (34). The combination of increased heat, increase in allergens, and worsened air quality related to climate change represents an important threat to respiratory health.

Climate-related respiratory health threats are not experienced equally among all populations. When compared with high-income non-Hispanic White communities, historically marginalized/excluded and low-income communities are disproportionately exposed to air pollution and experience barriers to accessing quality health care to mitigate their impacts (35, 36). These factors increase the susceptibility of community members when climate-sensitive events occur. For example, in the United States, Kerr and colleagues found that NO_2 and $PM_{2.5}$ concentrations in the census tracts with predominately marginalized groups were 110% and 16% higher, respectively, than in the most-White census tracts (37). Such unequal exposures are rooted in structural racism and manifest in health disparities (35). Structural racism, including historical redlining, residential segregation, poor education systems, workplace policies, and other forms of discrimination, limit opportunities, impair wealth, and threaten the well-being of people based on race, ethnicity or other status (38). Historical redlining (and modern housing segregation), as a manifestation of structural racism, as well as subsequent wealth inequities, is associated with increased exposure (e.g., heat and pollution) and worse respiratory outcomes, including increased risks of childhood asthma and COPD diagnoses (39). EJCs often reside within "sacrifice zones," regions of unwanted land resulting from

Table 2. Workshop participants

Academia: United States
Susan Anenberg, Ph.D. (George Washington University, Facilitator)
John R. Balmes, M.D., A.T.S.F. (University of California, San Francisco, Facilitator)
Tarik Benmarhnia, Ph.D. (University of California, San Francisco, Facilitator)
Juan C. Celedón, M.D., Dr.P.H., A.T.S.F. (University of Pittsburgh, Speaker)
Daniel P. Croft, M.D., M.P.H., A.T.S.F. (University of Rochester, Co-Chair)
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Ilona Jaspers, Ph.D. (University of North Carolina, Mentor)
Gaige H. Kerr, Ph.D., M.A. (George Washington University, Speaker)
Peggy Lai, M.D., M.P.H., A.T.S.F. (Massachusetts General Hospital, Advisor)
Alison Lee, M.D., M.S., A.T.S.F. (Mount Sinai, Co-Chair)
Jennifer Maccarone, M.D. (Boston Medical Center, Fellow Mentee)
Pablo Méndez-Lázaro, Ph.D. (University of Puerto Rico, Speaker)
Nick Nassikas, M.D. (Beth Israel Deaconess Medical Center, Advisor)
Alexandra Noël, Ph.D. (Louisiana State University, Facilitator)
Tara M. Nordgren, Ph.D. (Colorado State University, Co-Chair)
Laura M. Paulin, M.D., M.H.S. (Dartmouth-Hitchcock Medical Center, Advisor)
Kent E. Pinkerton, Ph.D. (University of California, Davis, Facilitator)
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Mary B. Rice, M.D., M.P.H. (Beth Israel Deaconess Medical Center, Speaker)
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Neeta Thakur, M.D., M.P.H. (University of California, San Francisco, Co-Chair)
George Thurston, Sc.D. (New York University, Facilitator)
Sacoby Wilson, Ph.D., M.S. (University of Maryland, Keynote)
Academia/governmental: international
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Kalpana Balakrishnan, Ph.D. (Sri Ramachandra University, India, Speaker)
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Gillian C. Goobie, M.D., Ph.D. (University of British Columbia, Canada, Facilitator)
Vikas Kapil, D.O., M.P.H. (Emory University, Prasanna School of Public Health, Manipal, India, Speaker)
Professional societies
Gary Ewart, M.H.S. (American Thoracic Society, Speaker)
Community organizations
Cecilia Mejia, B.S. (Brightline Defense, Speaker)
Preshona Ambri (DC Environmental Justice, Facilitator)
Eddie Ahn, J.D. (Brightline Defense, Participant)
Governmental agencies
John Balbus, M.D., M.P.H. (Health and Human Services, Speaker)
Shereen D'Souza, M.S. (CalEPA, Speaker)
Stephanie M. Holm, M.D., Ph.D., M.P.H. (Office of Environmental Health Hazard Assessment, UCSF, Facilitator)
Chandra L. Jackson, Ph.D., M.S. (National Institute of Environmental Health Sciences, Speaker)
Sri Nadadur, Ph.D. (National Institute of Environmental Health Sciences, Mentor)
Claudia Thompson, Ph.D. (National Institute of Environmental Health Sciences, Speaker)

purposeful divestment or decades of damage from pollution and climate change such that it is deemed to be permanently impaired. Examples include the "cancer corridor" adjacent to refineries and fossil fuel operations in Louisiana or the community in Port Neches, TX, that resides near a chemical plant (40). Such disproportionate exposure and impact of climate change on EJCs emphasizes the need to better understand the drivers of the observed inequities. Generally, we distinguish three types of climate-sensitive exposure inequity: *1*) differential exposure, *2*) differential susceptibility, and *3*) differential resilience or access to climate adaptation resources (41–43). As Dr. Robert Bullard stated, communities that are disproportionately exposed experience disproportionate disease "first, worst, and longest" (44).

Although each climate-sensitive exposure can be a threat to respiratory health, cumulative exposure in an EJC can lead to particularly harmful health effects. EJCs are at a baseline increased risk of heat-related disease because of increased ambient temperature from the physical built environment (asphalt, limited greenspace), causing a heat island effect (an example of a type 1 inequity, differential exposure) (45). Multiple climate-sensitive exposure events (i.e., compound events), such as extreme heat and wildfires (46, 47), can jointly occur in marginalized communities with higher rates of chronic diseases, leading to worse health outcomes (example of type 2 inequity, differential susceptibility). Moreover, extreme heat can compromise electrical grid resilience and operationality. Although wealthier communities have more access to cooling infrastructure with backup power sources during outages, lower-income communities may not have access to air conditioning, backup power, or the ability to escape the heat (an example of type 3 inequity, differential resilience) (48, 49). Natural disasters such as tropical cyclones and flooding can also lead to worsened respiratory health through the promotion of mold and other allergens (31) and can worsen already existing exposures from

industrial sites or legacy cleanup sites, further threatening the health of adjacent communities (50). Because episodes of concomitant climate-sensitive exposures are most likely to impact already disproportionately affected communities (51), future research should focus on mitigation and adaptation approaches during these extreme events. Although we have provided a brief review of climate change related health effects, regular reports by the Intergovernmental Panel on Climate Change (2), Integrated Science Assessments by the EPA on air pollution (30), and the annual *Lancet* Countdown (52) are examples of helpful resources for regularly updated information on the health effects of climate change.

Addressing Environmental Injustice and Health Effects of Climate Change

Workshop participants identified changes, within a socioecological framework, needed at the individual, community, and societal (including global, regulatory, and legislative) levels to decelerate the climate crisis and improve health, particularly within EJCs (Figure 1). The following discussion describes the details of Figure 1, which serves as a preview of the potential strategies that are discussed in EJ and Community Partnerships in Climate Mitigation and Adaptation and Including EJ in Policy and Priority Research Infrastructure Needs to Address Climate Change. At the global/societal level, emphasis on policies and regulations that reverse the harms from structural racism, eliminate environmental injustice, and address agricultural mismanagement is critical. There is also a need to focus on changing societal behavior to curtail harmful human activities that worsen climate change, including minimizing fossil fuel burning and use (transportation, energy, manufacturing). Furthermore, an equitable world needs to

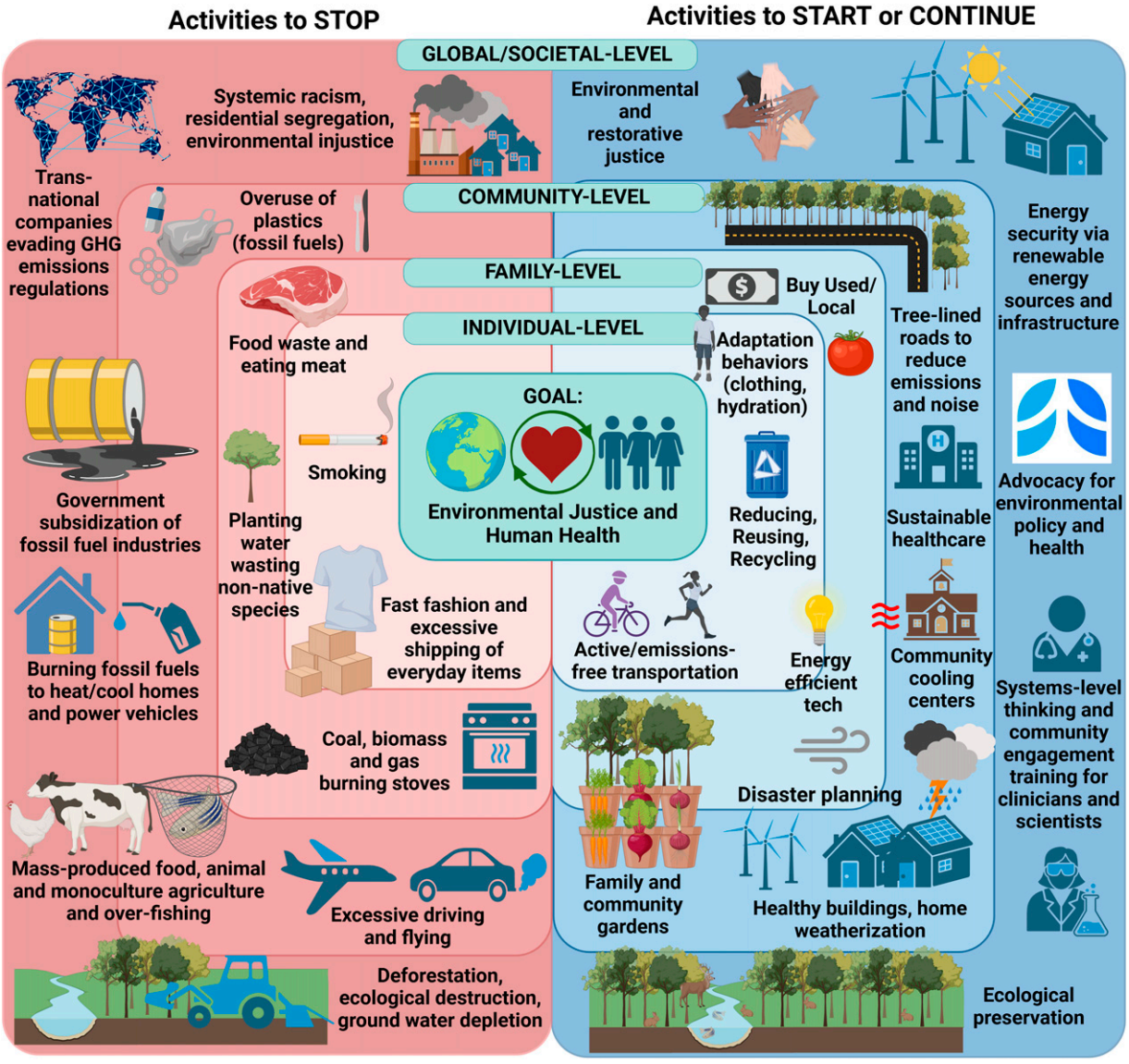


Figure 1. Outline of recommended activities to stop (left, red background) and activities to start (right, blue background) to address climate change and environmental justice. Rings of activities represent global societal level (outer ring) to individual level changes needed to reach the ultimate inner goals of environmental justice and human health (teal center section). Image produced with Biorender. GHG = greenhouse gas.

incorporate restorative justice practices, push for global renewable energy together with ecological preservation, and call for adaptative behavioral changes. From the community level to the individual level, behavioral change is needed to decrease wasteful consumerism (including fast fashion and excessive use of plastics), and to support smoking cessation. Governmental incentives are needed to support the creation of necessary infrastructure (including improved rail systems and public transportation) to shift our demand away from fossil fuel–intensive activities (e.g., flying and driving internal combustion vehicles) in a cost-appropriate way to ensure equitable green infrastructure expansion in all communities. With similar incentive support, society will need to increase the demand for the use of renewable energy in homes and mindful travel, including active transport (walking/cycling) and public transportation (rail/bus) when possible. For impactful and sustainable change, this approach needs to center on EJ concerns, prioritizing and creating fluid channels of communication between communities, large corporations, and governments to facilitate the codevelopment of solutions that are equitable and effective for all.

EJ and Respiratory Health Issues Affecting LMICs

Climate change, air pollution, and environmental injustice threaten respiratory health worldwide. Despite minimal contribution to the worsening of climate change, LMICs are suffering from severe climate-sensitive exposures. Areas such as Sahel and East Africa, the Middle East, the Indian subcontinent, and parts of northern and western China are expected to be most adversely impacted by climate events (e.g., desertification) (4, 5, 53). When discussing LMICs, workshop participants focused on inequity in exposure while highlighting issues within two important industrial sectors, agriculture and healthcare, because these sectors have global relevance and are expected to be put under stress by the changing climate. Although workshop participants recognized that energy production is another crucial sector driving climate change and air pollution, forming country-specific recommendations in the setting of complex global geopolitical forces and differing economic systems was judged to be beyond the scope of the workshop. Rather, changes to energy production are discussed within the context of the workshop aims.

Inequities in Exposures

Persons at highest risk for the health impacts of climate change are in vulnerable groups, including people who are pregnant, children, and those with chronic diseases in under-resourced and/or marginalized communities (54, 55). Globally, 90% of the poorest 1 billion people live in sub-Saharan Africa, and, of these, over 80% experience five or more deprivations defined by the global multidimensional poverty index (56), including climate-relevant risk factors such as nutrition, use of solid cooking fuel (biomass), and access to clean drinking water and electricity. In addition to being hazardous to health, these deprivations are amplified by a changing climate that threatens food security and increases the likelihood of housing displacement from natural disasters. Furthermore, adaptation tools to offset climate change, such as air conditioning or indoor air cleaners, are not always accessible. These inequities necessitate an EJ perspective in all programs that seek to address climate and health.

In the setting of droughts related to accelerating climate change, and desertification, dust clouds and storms are expected to increase in frequency (57). These sand and dust storms lead to soil salinity and widespread rangeland degradation and pollute the environment and agricultural production by deteriorating the physiological functions of plants, especially during pollination and inflorescence (53). Furthermore, dust-related events can increase exposure to *Coccidioides* spores and hazardous conditions for automobile and aviation safety (58). Epidemiological studies observe an association between desert dust storms and emergency department visits, hospitalizations, and death from respiratory diseases, including asthma, COPD, respiratory infections, and pulmonary emboli, and these studies also suggest that individuals in LMICs are more susceptible to these deleterious effects (5, 59). Although complex interactions between climate, pollution, and respiratory health can have unique features in different geographic areas, two industrial sectors central to EJ worldwide are agriculture and healthcare (Figure 2).

Agriculture. Desertification and resultant dust storms can combine with other climate forces to threaten food security through reduction in crop yields and nutritional quality, potentially turning 12 million hectares of land (20 million tons of grain) into deserts each year (60). The yields and nutritional content of crops can be reduced from increased pests, extreme weather, drought, and reduced land use (61, 62). These climate impacts disproportionately affect small farm holders, island communities, and LMICs with limited monetary/resource capacities to adapt to climate change (61, 63, 64). For example, decreases in grain and wheat crop production from climate change are expected to negatively impact inhabitants in 30 countries in Africa and Asia, who are highly dependent on grain production (5). The resultant impact on food security is a major concern for already overburdened populations (65–67). Furthermore, undernourishment is a risk factor for chronic pulmonary diseases such as COPD and asthma, as well as respiratory infections such as tuberculosis (8). Lack of access to nutrient-dense food also affects educational attainment, career advancement, and social capital (68–70). Increased temperatures and reduced rainfall leading to desertification, as well as deforestation, water overuse, and overgrazing of farmlands, increase the risk of food insecurity and its adverse effects on human health (71). In addition to global food insecurity, farm workers are directly affected by a disproportionate exposure to chemicals, dust, and heat, leading to lifetime increased risks of injury and disease, including respiratory illnesses such as asthma, COPD, sleep apnea, and lung cancer (72–75).

Industrial agriculture accounts for ~10–12% of total climate-forcing human-made emissions and contributes to climate change (76). The greatest contributors to agricultural emissions are methane from dairies and animal husbandry, fossil fuel use for fertilizer and pesticide production/application, water consumption for animal and crop production, and deforestation (77–80). Thus, current agricultural practices harm human health indirectly by imperiling food security and worsening global climate change, and directly by exposing farm workers (including migrant populations) to respiratory and other health risks (81). Adding to these risks is the increased reliance on antibiotics in industrial animal husbandry (e.g., concentrated animal feeding operations), leading to the emergence of new antibiotic resistance among pathogens that

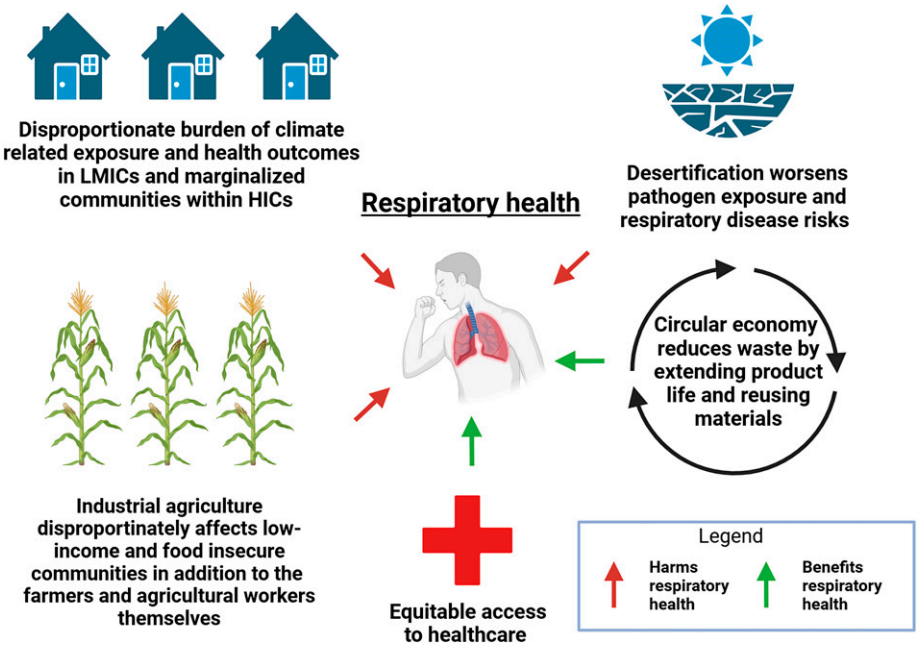


Figure 2. Summary of exposure and respiratory health in LMICs. Image produced with Biorender. HIC = high-income countries; LMICs = low- and middle-income countries.

can infect humans directly and more broadly through environmental contamination via ineffective waste management tactics (82–84). Notably, the development of antibiotic resistance in these pathogens threatens human health and puts global food security at further risk because of potential loss of animals from infections and from the culling of herds or flocks to prevent spread of emerging pathogens (85, 86). Climate change acts as a "threat multiplier" that increases the risk of conflict over increasingly scarce resources such as food and water, further displacing populations into overcrowded living conditions, with subsequent morbidity and mortality from health- and violence-related threats (87, 88).

Health care. Health and, we posit by extension, health care are human rights necessary for a productive and just society. LMICs and marginalized communities in high-income countries often lack access to basic health care (89). Although necessary for human health, the healthcare system is also a major contributor to climate change (90). For example, the U.S. healthcare sector accounts for 17.3% of the gross domestic product (91), 8.5% of the U.S. GHG emissions, and one-fourth of all global healthcare GHGs (90, 92). Of the 5–6 million tons of healthcare-generated waste each year, 75–90% is considered nonhazardous (and thus disposed together with normal trash in landfills and incinerators), and the rest is considered regulated medical waste destined for incineration or autoclaving (93). Landfills and waste incinerators are disproportionately located in marginalized communities. Indeed, 79% of municipal solid waste incinerators were in low-income communities or communities of color in 2019 (93–95). Although assessing health effects of waste incineration is challenging because of the heterogeneity in exposure (including PM, dioxins, heavy metals, and polycyclic aromatic hydrocarbons), concerns for carcinogenicity, adverse birth outcomes, and other organ-specific diseases are present (96, 97). Though the literature base on medical waste is stronger in high-income countries, healthcare systems in LMICs are also faced with the challenge of responsibly handling medical waste. For example, in Africa, over 67,740 health facilities generate roughly 282,447 tons of medical waste each year, with incineration being the main approach to disposal (98). The enhancement of medical waste–handling strategies in LMICs that also emphasize the principles of the circular economy (recirculating products at highest value and eliminating waste) (99) has the potential to improve human, environmental, and economic health (98). In summary, combining the direct and indirect emissions from energy use and other operations of the healthcare industry outlines the duality of health care being both a benefit and a threat to health. Building a less wasteful and more sustainable healthcare system can help reduce the health effects of climate change on disproportionately impacted communities.

EJ and Community Partnerships in Climate Mitigation and Adaptation

Community Empowerment and Partnership

Partnering with communities is important to achieving sustainable and equitable climate solutions, which will help mitigate climate-related respiratory health effects. In an effort to emphasize the community as the focal point of this section, we focus on the rationale and strategies for partnerships rather than the respiratory health outcomes discussed previously. Research and public health organizations, in partnership with EJCs, need to coidentify needs and priorities and codevelop strategies for climate adaptation and resilience. In traditional research models, the line of inquiry is dictated by the subject matter expert, and research is completed on or for a specific community. In such models, the researcher determines the research question, study design, and analytical plan, leaving the community as a passive participant in the process, even when the research conducted may be beneficial. When facing complex social problems, such as combating the effects of climate change on the health of socially vulnerable communities, traditional models break down. An approach that incorporates community knowledge and is aligned with community-defined priorities is essential to addressing structural and social factors that compound the health effects of climate change and developing mitigation strategies to reduce health effects. Although principles of community-based participatory action research are an effective mechanism for engaging communities to address the negative effects of climate change, it is neither appropriate nor feasible for every research question (100, 101). For example, although a study using a large administrative dataset may be informed by community groups, it may not be feasible for such groups to partner in the study design if highly specialized biostatistical methods are

employed (e.g., unacceptably high time demand to learn these methods). If a research group lacks appropriate training in engagement practices and understanding research ethics, concerns of research "tourism" could foster mistrust within a community. However, all research would benefit from shifting toward centering community voices and priorities. To move away from research models that traditionally, at best, only inform communities, we use the National Institutes of Health (NIH) continuum to describe how the scientific community may take purposeful actions to consult, involve, collaborate, and share leadership with community members and groups (102).

Figure 3 shows an ascending degree of engagement from a small amount of community involvement (Outreach) to a robust partnership with the community (Shared Leadership). Ultimately, academic scientists must leave their "ivory towers" and better connect with communities to achieve the trust and respect required to relay the dire circumstances associated with inaction in the context of our changing climate. **Outreach** to communities fosters information sharing, where the research team decides how best to translate results in understandable ways and demystify scientific concepts by conveying key points via accessible videos, using comedy and/or audience-appropriate language (e.g., different ages, levels of expertise). An example of this would be personalized messaging to help older adults prepare for extreme heat events (103). By **Consulting**, the research team creates a formal process, such as advisory boards, to facilitate feedback on the research agenda. Assessing the perceptions of climate adaptive strategies in Nepal is an example of the information sharing that is facilitated by consulting (104). Increasing levels of engagement includes **Involving** community members as active contributors in research plans and actions (e.g., as coinvestigators or community health workers in the Nature's Cooling Systems project [105]). **Collaborative** approaches are centered on partnered work, such as assisting communities with scientific endeavors (such as characterizing the health effects of air pollution as part of an effort to reduce burning of plastic waste in Guatemala [106]) that are more easily managed by the academic community. **Shared Leadership** represents a true, cohesive collective effort where researchers and communities are equal participants in all decisions, plans, and processes. The Food Equity and Environmental Data Sovereignty Project highlights the benefit of citizen scientists working collaboratively with research teams (107).

Although we have reviewed a small number of aspirational examples that exist, there have been limited efforts to engage communities in the design, testing, and implementation of community-based mitigation strategies, despite the success of these efforts being dependent on matching interventions to local needs and priorities (108). Furthermore, although increasing literature documents the disproportionate impact of climate change in socially vulnerable and marginalized communities (5), these groups have not been engaged in decision making for climate mitigation, strategy, and adaptation testing. To accelerate our understanding of which mitigation interventions should be widely implemented and incorporated into policy, community stakeholder priorities should be atop the research agenda. For wide-reaching policies to address climate change, we must expand the definition of community to include policymakers at the regional, national, and international levels.

Solutions to Overcome Barriers to Partnership

To achieve authentic partnerships, we must *1*) acknowledge historical and current actions that have contributed to ongoing mistrust of climate change efforts, *2*) value sociocultural differences and skill-set differences to reduce overt and unconscious power imbalances, and *3*) emphasize a community-first model that brings community partners to the table at the start of planning and increases transparency in decision making. Two programs that address these barriers include the HERCULES program in Europe (Sustainable Futures for Europe's Heritage in Cultural Landscapes) (109) and the Center for Ecoliteracy in California (110). Community-based participatory research incorporates features that facilitate many of the research, policy, and patient care goals of the ATS (111). Active community involvement in research has been shown to address environmental injustice, particularly when community members are included in leadership roles (112) (Figure 4).

Several U.S. federal agencies have shifted their framework to center on community engagement to develop transdisciplinary transformative research. As described by the NIH Climate Change and Health Initiative Strategic Framework, public health interventions that are rooted in partnerships with vulnerable communities will ensure recognition of community-relevant impacts of climate change and create evidence for equitable practices for climate adaptation and building health resilience (113). To support a foundational structure of

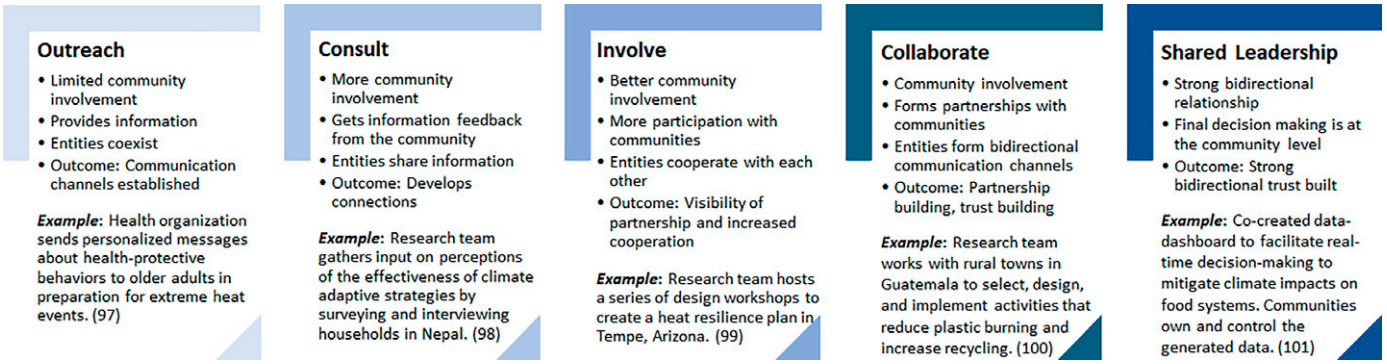


Figure 3. Adaptation of the National Institutes of Health Continuum for Community Engagement (source: National Institutes of Health).

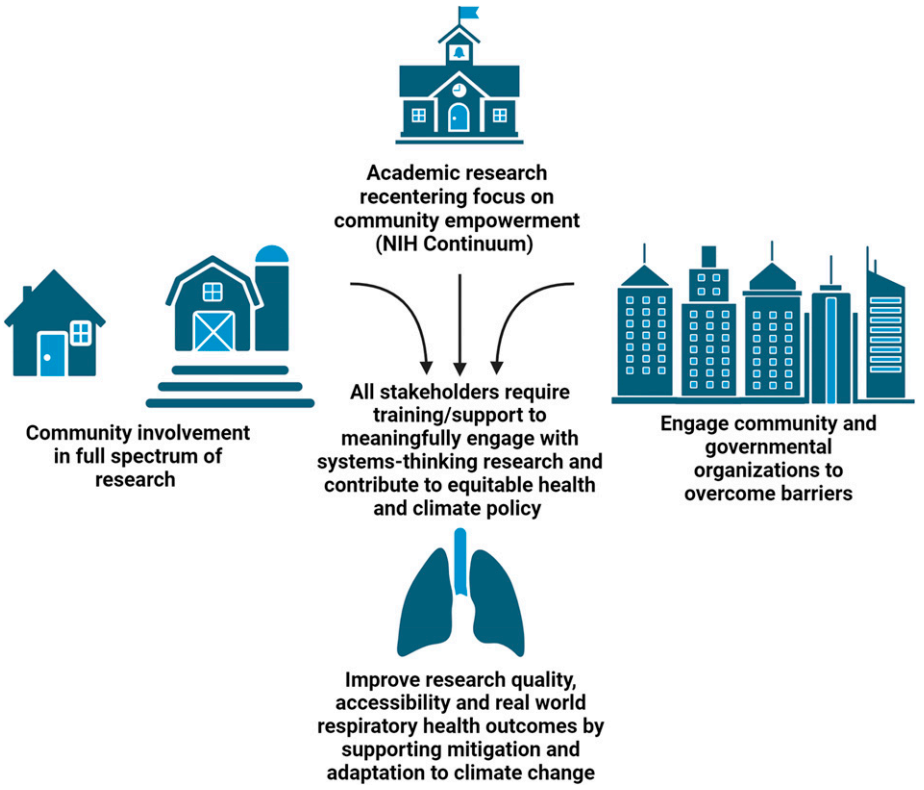


Figure 4. Summary of community involvement in climate mitigation and adaptation. Image produced with Biorender.

community engagement in climate research, the NIH launched the Alliance for Community Engagement – Climate and Health to empower community-driven sustainable strategies to address the impacts of climate change on vulnerable communities. A similar effort was recently launched by the EPA. The Inflation Reduction Act (IRA) Community Change Grant Program has earmarked US $2 billion for EJ communities to address pollution, increase climate resilience, and build capacity to address climate change (114). The Centers for Disease Control and Prevention (CDC) is also shifting focus from simply listing the markers of health disparities to identifying and addressing the drivers of those inequities as a foundational element across all CDC activities. The CDC's CORE commitment strategy is working with multidisciplinary partners to *C*ultivate comprehensive health equity science, *O*ptimize interventions, *R*einforce and expand robust partnerships, and *E*nhance capacity and workforce engagement. This shift represents a growing understanding that top-down approaches will not be as successful as community-engaged and -centered approaches. For example, the small, historically Black community in Elba, MS, named Shiloh is receiving attention as a bellwether of how the IRA can affect meaningful change. Because of worsened rainfall from climate change, Shiloh has suffered from flooding after construction of a nearby highway in 2018. The suspected culprit of the severe flooding that is destroying homes' foundations and septic fields are the highway's drainage systems that "are pointed like cannons into the community." A community-informed investment would be to address the drainage system of the highway. Robert Bullard has said that as part of the U.S. White House EJ Advisory Council, "if I can't get justice for Shiloh, I need to knock my name off of that, quote, 'father of environmental justice'" (115).

Including EJ in Policy and Priority Research Infrastructure Needs to Address Climate Change

Tools to Approach Climate, Health, and EJ on a Legislative Level

Approaches to reducing human-generated GHG range from global, societal, and resource-appropriate individual-level efforts to reduce the use of fossil fuels to power automobiles and heat and cool houses and businesses. Both state and privately owned fossil fuel companies will need to be incentivized to minimize their extraction of fossil fuels and support retraining programs for existing employees to renewable energy projects, particularly those that can reuse existing infrastructure (e.g., converting onshore oil/gas wells to geothermal energy generation) (116). Simultaneously, manufacturers will need to account for and manage direct emissions (scope 1 emissions) and emissions that arise as consequences of the company's activities (scope 2 and 3 emissions) (117). Elimination of our dependence on fossil fuels will need a comprehensive, multilevel strategy that includes governmental incentivization and corporate realignment to accelerate the development and implementation of renewable energy (e.g., solar power), electrification and weatherization of homes with optimal ventilation, buttressing the electric grid to handle the increased demand, and engaging in individual-level climate adaptation behaviors, including using active transport, avoiding retail overconsumption, and limiting meat intake (118) (Figure 1). Within this multilevel strategy, a just transition will need to be supported to ensure equitable access to resources such as renewable energy and electric vehicles because the relative benefits can be greatest to groups with low income (119).

Healthcare and research partnerships with EJ communities can help identify priorities and potential solutions for climate change and environmental injustice. In turn, adopting and implementing policies to address priorities in climate change will require legislative and regulatory actions at the local, state, federal, and international levels. To date, enactment of the IRA (P.L. 117-169) has been the most significant legislative action the United States has taken on climate change. Although containing other consequential tax and healthcare provisions, the IRA is primarily a climate change law designed to move U.S. industrial policy on a path toward GHG emissions reduction. The law takes a "carrot" approach (e.g., federal subsidies) to encourage adopting technologies to reduce GHG emissions and adopt low or GHG-free energy sources. Although not certain, many climate policy experts believe the IRA gives the United States a chance at meeting its

goals of 50% GHG reduction from 2005 levels by 2030, 100% carbon pollution-free electricity by 2035, and net zero economy emissions by 2050.

Although effective, using "carrots" as a policy tool will not suffice to realize essential climate goals, and, as such, "sticks" (regulations) will need to be simultaneously implemented. Effective May 7, 2024, the EPA has implemented 89 Fed. Reg. 16820, which will significantly reduce fugitive methane gas emissions from petroleum extraction and refinement. The EPA has implemented other major rules to reduce GHG emissions from the electrical power industry and car and truck tailpipe emissions. An underappreciated benefit of the EPA's rules on reducing criteria pollutant emissions (PM), including the recent reduction of the annual $PM_{2.5}$ standard to 9 $\mu g/m^3$ (120), is that these changes also will reduce GHG emissions. With the optimal combination of incentives and regulations, a senior climate reporter has assessed that "it's now cheaper to save the world than destroy it" (121).

States also have a role in both creating and enforcing environmental regulations. For example, the Clean Air Act allows California, the world's fifth largest economy, to set state emission rules that are more protective than the federal EPA policy. California has successfully used its authority to develop regulations to reduce emissions from maritime vessels, cars, and heavy-duty trucks. Several states have adopted California standards, helping accelerate U.S. efforts to reduce GHG emissions. Although California is a clear leader in this area, many U.S. states (33 of 50) have released a climate action plan that either mirrors the California "100% carbon-free electricity by 2045" plan or is unique to their own geography and industries (122). Specifically, 23 states plus the District of Columbia and Puerto Rico have set aggressive carbon-free (or zero-emissions) electricity goals with target years ranging from 2032 to 2050 (123). Although tremendous progress has been made nationwide, there have been calls by specific communities for equitable enforcement of environmental regulation. Communities in Southern California recently reached a legal settlement with the South Coast Air Quality Management District (AQMD) to compel the South Coast AQMD to collect fines from major polluters in the region that had previously escaped penalties (124). Other communities may lack the resources to take legislative action, but the National Caucus of Environmental Legislators is a nationwide group able to support legislative solutions to environmental problems and to help communities across the nation achieve EJ goals (125). Legislative efforts tie into the concept of restorative justice, which seeks to repair a harm that is done while holding the offender accountable (126). Although restorative justice is typically thought of at an individual level, the "polluter pays" principle could be thought of as a societal level restorative justice action.

Agricultural Policy

Agriculture plays an essential role in maintaining global health and can be considered multipronged in its relationship to climate change and health impacts. Common practices in the agriculture industry (e.g., use of monoculture farming, feedlots/confined animal feeding operations, antibiotic overuse) significantly contribute to GHG emissions and climate change while also harming ecosystems and soil health and making inefficient use of land resources. Specifically, large-scale monoculture/crop practices deplete soil health while also increasing susceptibility to plant disease and pests that threaten crop viability (127). Because the agriculture industry is also central to food security, these current practices threaten the sustainability of nutritious crops. Thus, changes to the agriculture industry must address soil and ecosystem health, GHG/climate change contributions, land resources, and food security.

Regenerative agriculture practices (e.g., reduced water use, cover cropping and polyculture, crop rotations, minimal tilling) can improve crop adaptability/resilience to climate change and pests and promote both crop biodiversity and soil health, thereby creating an opportunity to promote more ecologically friendly and nutritious food options. Because regenerative practices promote soil health, there can be a reduction in the loss of phosphorous from farmland into waterways, thereby preserving limited phosphorous resources and limiting damage to aquatic ecosystems (128, 129). Climate benefits can also be realized by shifting conventional agricultural methods toward regenerative agricultural practices, including increasing soil carbon capture and lowering GHG emissions (e.g., decreased tractor use for tillage) (130). A multidisciplinary task force in Europe published a recent report detailing that the strategies needed to mitigate the climate effects of agriculture (including promotion of plant-based diets, reducing food waste, and more efficient fertilizer application) would also substantially decrease wasteful nitrogen losses within food systems (131). Because global nitrogen and phosphorous loss threatens food security, improving agricultural practices can benefit climate change and food security.

Effective policies must focus on promoting crop viability and diversity and on responsible livestock and milk production to reduce methane emissions, use available land, and prevent habitat destruction (132, 133). Although changes may not be feasible in LMICs, industrialized nations—as the largest contributors—hold the fiscal and resource capacity (including the additional land and initial investment needed for regenerative practices) to adapt current agricultural practices (134, 135). Specific to crop farming, although pesticides can help preserve harvests in monoculture farms, care must be taken because pesticide changes can yield new resistance and/or the emergence of new occupational hazards (136). Within the animal husbandry industry, reducing reliance on antibiotics, improving waste management protocols, and implementing sewage monitoring systems have the potential to reduce the emergence of antibiotic-resistant pathogens within animal and human communities (84, 137).

Shifting perception on agricultural approaches and how to manage land will be a key challenge. In addition to regenerative agricultural practices to address lack of soil health (or inefficient land use), the appropriate use for retired farmland will need to be considered. Although renewal energy options such as solar panels are typically discussed as an "either/or" proposition, pitting energy against food production, this can be a false choice. A recent U.S. Department of Energy study of solar energy sites on retired farmland reported increased biodiversity of plant life and native insect pollinators in the solar panel field (138), which has an additional potential benefit to adjacent active farming fields. This example highlights the bidirectional nature of the benefits of improving agriculture and climate-related practices.

To make these regenerative options more "mainstream," industry- and government-supported financial and cultural programs designed to encourage climate-friendly diets are also critically important,

including campaigns that encourage regional, culturally appropriate foods and limit meat consumption. Other potential solutions include having local farms' produce available through federal voucher programs, as well as using more specific language to define the problem of climate change. For example, when engaging with communities in agriculture, focusing on the topics of "soil conservation" and "changing ecosystems" rather than the broader term "climate change" may be more meaningful. Specific and relevant communication to community needs is likely to lead to greater productive engagement (*see* EJ and Community Partnerships in Climate Mitigation and Adaptation).

Global Climate EJ Issues: Research and Data Needs

Although climate change is driven by fossil fuel combustion in high-income countries and LMICs with rapid economic growth, climate change disproportionately affects those who have contributed the least (44), including persons living in LMICs without rapid economic growth. For example, although Africa has experienced large public health gains over the past decades, climate change threatens to slow or even reverse this progress (139). Compounding this, many LMIC governments do not routinely collect or leverage administrative data to quantify key societal vulnerabilities. Indeed, the Climate Impacts Lab estimated that "the effect of an additional very hot day (35°C/95°F) on mortality in the >64 age group is ~50% larger in regions of the world where mortality data are unavailable" (140). Thus, policymakers and communities are effectively operating in a data vacuum with respect to the health impacts of a changing climate. LMIC-led climate programs that integrate community and policy partner engagement, capacity building, and resilience will be most impactful for increasing meaningful collective participation and mitigating risk.

Data Policies

Differences in spatiotemporal resolution and data availability to the public increase the challenge of studying the health and EJ impacts of climate change across high- and low-income countries. By working with federal agencies, nongovernment organizations, and other community partners, experts can develop and refine tools that aid in screening (e.g., EPA EJScreen, CalEnviroScreen, and the US Climate Vulnerability Index) [141–143], as well as incorporate citizen science applications for data collection such as the Partnerships for Environmental Public Health (144).

Interagency collaborations, including the Environmental Public Health Tracking Program, and Climate and Health Outcomes Research Data Systems, can offer valuable opportunities to bridge scientific data portals, adopt a holistic perspective of relevant public health data sources, and strengthen public trust through building community communication and rapport. For datasets that do not fall under the purview of archival activities from any one federal agency or multiple agencies, investigators and their institutions should also find FAIR (findable, accessible, interoperable, and reusable)-compliant repositories for their datasets, seeking agency support when needed. We propose the following recommendations to improve data access, commensurability, and transparent community engagement, which should be supported by U.S. federal agencies on the basis of their established mandates and policies (e.g., Open Government Data Act of 2018, Year of Open Science 2023):

- **Data discovery:** Develop repositories summarizing the vast quantity of health and environmental data (>50 petabytes annually) (145), potential applications, and associated limitations.
- **Data access and processing:** Spatiotemporally align and distill big data in FAIR formats (146) to support diverse end users and enable multiscale analyses.
- **Centering EJ:** Adopt a systems-thinking and community-driven approach to generate or collect and own data (147), eliminating any further stigmatization of marginalized populations.

Considering health and equity impacts within governmental decision-making contexts is critical to designing mitigation and adaptation actions that improve EJ. Assessing quantitative impacts to population subgroups (e.g., children and persons with chronic respiratory diseases) and at higher spatial resolutions (e.g., at the census tract level) within regulatory impact analyses would provide more detailed information about how different policies would affect equity. For these reasons, integrated cumulative health impact assessments are needed to help influence data policies focused on EJ (148). Because these analyses are often constrained by data availability, modeling tools, and computational power, additional work to develop feasible approaches to quantifying distributional impacts, such as reduced form models (149), may be necessary. Attention should be given to hazardous air pollutants and markers of traffic-related air pollution, such as nitrogen dioxide (NO_2) and black carbon, in evaluating equity impacts of policies targeting pollution emissions. Metrics used to evaluate societal improvements from reducing GHG, such as the Social Cost of Greenhouse Gases, should also incorporate distributional impacts (150, 151). Committees developing and reviewing such approaches should include health expertise to ensure that health and equity are considered and that evidence-based approaches are used.

Building Resilience to Climate Change

Similar to the resource scarcity in LMICs, low-income and marginalized communities in high-income countries typically have less capacity to adapt to climate change. These communities have greater exposure to air pollution, lower housing quality, fewer green spaces, and limited access to high-quality health care (152, 153). Furthermore, these communities may have language and/or educational barriers to learning about strategies to adapt to climate change. Underlying the so-called climate gap between rich and poor communities, the most impactful of the structural determinants that lead to low resilience to climate change is poverty (153). Interventional strategies that overcome this "climate gap" must include interventions that put the onus on government and industry sectors to support changes versus relying on bootstrap efforts of the communities that are being impacted.

Despite increased exposure to air pollution, low-income and marginalized communities rarely have targeted monitoring of their exposures because EPA air quality monitoring and enforcement are done at the regional level. In addition, the pollution burden of a vibrant in-person economy (shopping/restaurants/entertainment) can be disproportionately placed on low-income and racially minorized communities. Specifically, a study during the COVID-19 pandemic lockdowns in California observed reductions in pollution for Asian and Hispanic communities

near in-person economy hubs, whereas predominantly Black communities did not experience a reduction in pollution exposure, because their sources (e.g., power plants) were not shut down (154). Given community-specific exposures, an exemplary policy action that empowers communities to self-monitor is California Assembly Bill 617 (AB617). AB617 mandates developing air quality monitoring and an emission reduction plan for disadvantaged communities (as designated by the California Air Resources Board) deemed to be overburdened by air pollution (155). This bill is designed to address historical environmental injustice and requires that local air districts work with community steering committees to develop both community air quality monitoring and emission reduction plans.

Decision support tools using Earth observation data can provide insight to community stakeholders on pressing health concerns and protecting population health. The tool developed by the University of Puerto Rico-Medical Sciences Campus Environmental Health Department now operational at the Caribbean Coastal Ocean Observing System, a government, academic, and community partnership, provides real-time usable data to those most burdened during an emergency. The Commonwealth of Puerto Rico (U.S. territory in the Caribbean region) recently experienced the disastrous effects of Hurricane Maria (2017), together with frequent earthquakes (e.g., 2020) and ongoing power outages because of an unstable power grid. One local research team in Puerto Rico identified Saharan dust storms as a naturally occurring phenomenon that impacted public health. This team formed more than 19 multidisciplinary community partnerships and used remotely sensed satellite data from MODIS (Moderate Resolution Imaging Spectroradiometer), VIIRS (Visible Infrared Imaging Radiometer Suite), and GOES (Geostationary Operational Environmental Satellites)-16 EAST data to track seasonal dust particles and develop an air quality forecasting tool to inform policy decisions and educate the public on the health risks of dust storms (156). This prototype application was launched by the University of Puerto Rico Environmental Health Department in June 2020, just before the historic ("Godzilla") dust storm (157). With this information, the Puerto Rico Department of Health added Saharan dust events to the list of emergencies that solicited seasonal ($PM_{2.5}$) public health advisories. Additional community outreach activities using in-person and virtual formats were made available to health centers and science museums, thereby increasing awareness about the harmful effects of $PM_{2.5}$ from dust events (158). This team's efforts represent a significant application of changes being supported by academic, government, and/or industry partners that led to increased community resilience while avoiding placing the burden of creating resilience on the community members themselves. To help support these climate programs worldwide, the ATS has invested in research capacity building in LMICs through the MECOR (Methods in Epidemiologic, Clinical, and Operations Research) Program (159). The historic measure to create a loss and damage fund for LMICs by international leaders at the Conference of the Parties will provide additional financial support for capacity building related to climate action (160).

Education of Health Professionals to Promote Civic Engagement

Although health professionals may not be the first group the public currently turns to for information on the health effects of climate change, emerging global health risks, such as climate change, air pollution, and zoonotic spillover, directly impact the delicate balance of living organisms within surrounding ecosystems. The complexity is captured by the concept of One Health, defined as "a collaborative, multisectoral, and transdisciplinary approach—working at the local, regional, national, and global levels—to achieve optimal health outcomes while recognizing the interconnection between people, animals, plants, and their shared environment" (161). As global leaders have recognized the interconnectedness of human, animal, and environmental health, the need for multidisciplinary collaborations that leverage expertise and data resources (such as GeoHealth sciences) has become evident (162). In support of these collaborations, education and training resources are essential to reinforce clinical and public health competencies on complex environmental topics. Because clinician-researchers will be a key group using improved data from understudied areas, training is needed for professionals involved in research to engage with the communities they serve. Such advocacy training and community involvement should also be moved into health professions education (163). Health professionals and researchers need training in risk communication for broad audiences, a base understanding of how environmental exposures can affect human health, and improved understanding of injustices in communities historically and currently affected by environmental health hazards, as well as climate mitigation and adaptation efforts. Recognizing the fast-paced learning environment of the health professions, the 4Cs of the One Health definition—communication, collaboration, coordination, and capacity building—can serve as a framework to help master acquired skills and competencies and apply the One Health approach to practice (164).

Although many ideas for improving environmental health and climate change education have been proposed (165, 166), the need remains (167, 168). A medical student–driven effort over the last 5 years, the Planetary Health Report Card, has systematically reviewed planetary health material within health sciences schools and identified multiple gaps in curricula (169). Existing efforts to improve environmental health education have included organization-wide faculty development initiatives (170), as well as "train the trainer" type models such as the Pediatric Environmental Health Specialty Units (PEHSUs) (171). PEHSU funds a network of environmental health professionals who educate a broad group of health professionals on environmental concerns for children, including EJ and climate change. The PEHSU network's Pediatric Environmental Health Toolkit (https://peht.ucsf.edu/) includes climate health information in a mobile-friendly format for just-in-time education of health professionals. Those in leadership positions within health professions schools should add climate action and environmental justice objectives as part of the curricula and leverage existing educational resources (172). Those learning objectives could include material on action-oriented steps that health professionals can take, including how to advocate for justice-based climate health policies in their local areas and how to provide expert testimony.

Resources can include continued medical education courses by professional medical societies such as the American Medical Association, the American Public Health Association, the American Academy of Pediatrics, and the ATS, as well as the Global Consortium on Climate and Health

Education. Additional opportunities to join work groups or communities of practice, such as the ATS Environmental, Occupational and Population Health Assembly's Early Career Professional Working Group or the Group on Earth Observations Health Community of Practice (173), can help physicians leverage their clinical expertise, share data and resources, and expand professional networks.

Sustainable Healthcare/Sustainable Academics

Although incorporating climate health effects into the education and training of health professionals in community engagement are needed, we must also address the climate impact of medical institutions. Reducing the carbon footprint of the healthcare system is achievable with a focus on *1*) decarbonizing the supply chain, which accounts for 82% of the emissions from U.S. health care, primarily related to pharmaceuticals and chemicals (90); *2*) optimizing healthcare use and delivery (e.g., eliminating unnecessary procedures, prioritizing primary care to reduce resource-intense healthcare use); and *3*) supporting local sustainability practices (e.g., energy conservation, zero waste, sustainable food, green commuting).

Healthcare organizations and environmentally focused governmental agencies, including the Agency for Healthcare Research and Quality and the EPA, have launched efforts to identify and find alternatives to suppliers with high GHG emissions, with funding support from the IRA (174). Transitioning to renewable energy to power hospitals must also be a priority, because eliminating fossil fuel burning benefits urban- to regional-scale air quality by reducing power plant emissions, thereby reducing the contributions of health care to global climate change. Indeed, the partnership between the Massachusetts Institute of Technology and the Boston Medical Center already obtains 100% of its power from renewable energy sources (175). Avoiding unnecessary tests and procedures is another way to improve the patient experience, save costs, and reduce waste. In the selection of products and supplies, healthcare institutions can formally incorporate the climate impact into decision making by performing life cycle assessments that evaluate the comparative costs and carbon footprints of each alternative, such as reusable and single-use devices (e.g., laryngoscopes), personal protective equipment, and medications (e.g., inhalers) (176–178). Reconsideration of which patients require contact precautions in hospitals can also reduce waste without harming patient care (177, 179). Such actions can be institutionalized by creating a team within a hospital network with diverse skills, including life cycle assessments, waster, sustainability, clinical care, and quality improvement.

As the medical field attempts to reduce its GHG emissions, we must recognize the fossil fuel industry's inaction despite decades-old knowledge of its harmful contribution to climate change (180). Taking a comprehensive view of industry emissions is important when considering the pros and cons of potential solutions for our healthcare systems. For example, when considering the relatively small but present emissions from hydrofluorocarbon (HFC) inhalers, we must weigh the potential reduction in GHG emissions with impacts on the respiratory health of patients with respiratory disease. Currently, many metered-dose inhalers (MDIs) use HFCs (powerful GHGs with a global warming potential [GWP] more than 1,000 times that of CO_2) as a propellent. The U.S. Food and Drug Administration, EPA, and European Medicines Agency are encouraging drug manufacturers to transition from MDI propellants with high GWP to alternative propellants with lower or no GWP. As the Global Initiative for Asthma considered the trade-offs of the possible benefit of moving away from fluorinated gases or polyfluoroalkyl substances in inhalers, the unintended consequence of cost-driven restrictions on inhaler access for patients with asthma in LMICs was discussed (181). In addition, children, elderly patients with poor lung function, and patients with neurologic or cognitive limitations will require MDIs because they cannot effectively use alternative inhalers (dry powder inhalers) (182). Finally, awareness and avoidance of creating "green guilt" in patients who use HFC MDIs were raised as potential barriers to adherence and a risk factor for exacerbations. Other examples of opportunities to save emissions within health care include using telemedicine visits to lower transportation-associated emissions and digitizing educational or care instruction printouts to save paper. Although beneficial to the environment, these approaches may restrict access to care or information for individuals with limited or no telephone or internet connection. With no simple answers in advancing climate goals while ensuring equitable patient care, we must think carefully about trade-offs within our climate policy positions. Although MDIs, telemedicine, and paper usage are within our practice sphere, we must recognize that aggressive reduction of emissions from any one of these activities without significant reductions in emissions from fossil fuel extraction and use is unlikely to achieve our goal to slow the harmful effects of climate change. The summation of research and policy needs is detailed in Table 3.

Role of Medical Societies

Professional medical societies such as the ATS and other members of the Forum of International Respiratory Societies (183) have a responsibility to respond to climate change, a health and EJ issue. ATS has served as a policy leader in climate change since 2008, after ATS members authored a policy statement characterizing climate change as a human-made threat to health (184). This ATS stance was later adopted by the American Medical Association. ATS has commented in support of several EPA-proposed regulations to reduce GHG emissions, advocated in Congress for climate-responsive policy, and participated in several court cases to preserve EPA's authority under the Clean Air Act to regulate GHG emissions. The ATS Environmental Health Policy Committee has helped define the health consequences of increased heat (185), estimated the burden of wildland fire smoke exposure (a consequence of climate change) in the United States, and developed a more comprehensive social cost of carbon estimates (150, 186), which are essential to guiding effective climate change policies. As part of these efforts, ATS has called for additional research on the social cost of carbon, climate change adaptations and remediations, and wildfire smoke (e.g., characterization, chronic effects, and prevention).

The ATS can contribute to the call to action by engaging in multisector activities that result in reduced emissions and protect respiratory health. Given the need for public health interventions to promote sleep health (187), the ATS should help champion the actions recommended by the International Pediatric Sleep Association and World Sleep Society (188): *1*) advancing research on the effects of climate change on health inequities and catalyzing transformative actions to translate research into practice (e.g.,

Table 3. Key research priorities to close the climate gap

Academic
Educating health professionals and scientists on civic engagement is a key part of helping facilitate multisectoral collaborations.
Incorporate the One Health framework (human-animal-environment nexus) into building multisectoral collaborations with communities that leverage expertise to examine health-related hazards, identify at-risk populations, and develop action plans that strengthen preparedness.
Research
Focus research on the drivers and indicators that increase exposure to harmful emissions within at-risk communities through exposure and epidemiological studies, community-based participatory research, and systematic reviews.
Develop operational tools and resources for climate action and adaptation, including multisectoral surveillance, early warning systems, targeted prevention and threat reduction, community engagement, and increasing public awareness.
Integrate environmental and health hybrid databases from diverse data sources (e.g., satellites, *in situ*, public health) to support accurate risk modeling and decision-making activities on pressing environmental topics.
Policy
Use integrated cumulative health impact assessments to help implement early warning and/or response systems for increasing dust, wildfire smoke, and extreme heat events in local communities, which could provide tailored recommendations to alleviate the respiratory disease burden in marginalized communities.
Incentivizing regenerative agriculture methods, cultural programs to enhance demand for and access to climate-friendly diets, and support of local farms can promote resilience to the negative health impacts of the agriculture industry.
Adopt practices within the healthcare system that reduce its carbon footprint while also improving educational strategies for both healthcare workers and patients to understand the health impacts of climate.

California's Fourth Climate Change Assessment [189]), *2*) disclosing the energy impact of long-term ventilation of indoor spaces and consideration of renewable energy sources, *3*) refusing sponsorship of society meetings by the fossil fuel industry, and *4*) reducing carbon footprints associated with professional meetings (e.g., choosing Leadership in Energy and Environmental Design (LEED)-certified facilities for meetings, reducing meeting waste, facilitating reductions of meeting transportation emissions [e.g., hybrid meetings]). In addition, there are important "niche" issues such as MDI propellants, which, although a small contributor to overall global GHG, can help treat patients with respiratory diseases. The ATS will continue to play a role in clinical decarbonization efforts by working with the drug industry, regulators, patient groups, and physicians to ensure a potential MDI propellant switch is conducted in a way that responds to climate change while ensuring access and affordability of MDI medications for all patients. ATS can also engage with medical boards to ensure that the health effects of climate change and pollution, together with environmental equity considerations, are adequately represented in standardized testing. Because ATS is a leader within the policy field, we must innovate in our approach to maximize our impact. Specifically, when considering climate and health policy going forward, the ATS will endeavor to start with health equity as a central tenet of policy development to ensure we develop and support policies that will be effective, durable, and equitable. The ATS will continue to be a vigilant advocate for respiratory health and EJ as the global economy moves to carbon-free energy sources and equitable adaptation to future climate-forced health and environmental challenges.

Other Technologies

In addition to the many beneficial approaches to climate mitigation and adaptation mentioned, there is active research and investment in other potential solutions to climate change, including carbon capture, use, and storage (CCUS) technologies. Although discussing the pros/cons of these approaches is beyond the scope of this report, avoidance of creating GHGs in the first place using previously mentioned approaches can help avoid the inefficiencies and potential inequities of trying to remove CO_2 from the environment after its creation (190). Although we acknowledge the likelihood of CCUS being one strategy employed by governments to mitigate the harmful effects of climate change, we advise against it being viewed as replacing the necessary transition to renewable energy, reducing energy use, or improving the efficiency of energy use. Specifically, we must also consider the EJ impact of CCUS, which has the potential to cause air and water pollution and other harms in vulnerable communities. Because CCUS is a component of California's plan to reach carbon neutrality by 2045, a coalition of EJ groups in the state assessed that "most engineered carbon capture increases air pollution, water pollution, and other harms for frontline communities" and urged avoidance of wasting resources on current CCUS, calling it a "climate dead end" (191).

Conclusions

Although mitigating the respiratory health effects of climate change is challenging, the benefit to the disproportionately affected EJ communities will be immense. To make a meaningful change in the current climate crisis, there will need to be changes to the status quo approach to transportation, energy production, and everyday life activities. By involving without overburdening our communities in climate policymaking, we can expect maximal benefits. As clinicians, researchers, policymakers, and advocates for equity and improvement of respiratory health, we have a duty to improve the future for citizens. As Hazel Johnson, the "mother of EJ" said, "If we want a safe environment for our children and grandchildren, we must clean up our act, no matter how hard a task it might be" (192). ■

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