# WMHP


## WORLD MEDICAL & HEALTH POLICY

VOL. 13 NO. 1 MARCH 2021


CONTRIBUTIONS




*(Contents continued on page 171)*

# World Medical & Health Policy

## Aims and Scope

***World Medical & Health Policy*** is a quarterly, peer-reviewed journal that considers the many factors shaping global health. We publish articles employing overlapping disciplines that include health policy and politics, political science, health economics, medical ethics, and public health. The journal's approach is unified by a thoroughgoing concern with critically examining the contexts within which policy is made, as well as more traditional considerations of processes, outcomes, and influences.

In converting empirical evidence into policy, ***World Medical & Health Policy*** helps policymakers design and promote programs that improve health outcomes, particularly for vulnerable populations. By bringing a global policy perspective to medical practice, the journal navigates the often-tangled world of global economic imperatives, international diplomacy, international agreements, the law, natural and humanmade disasters, humanitarian interventions, the social determinants of health, and local and international standards of care. The journal is committed to publishing practitioners' opinions and case studies alongside academic research articles.

## Copyright and Copying (In Any Format)



## Disclaimer

The Publisher, Policy Studies Organization, and Editors cannot be held responsible for errors or any consequences arising from the use of information contained in this journal; the views and opinions expressed do not necessarily reflect those of the Publisher, Policy Studies Organization, and Editors, neither does the publication of advertisements constitute any endorsement by the Publisher, Policy Studies Organization, and Editors of the products advertised.

Proceedings of the Policy Studies Organization are available online at http://www.psocommons.org/proceedings.

World Medical and Health Policy



# Editorial

**Daniel Skinner**

Readers of *World Medical & Health Policy* are critically aware that 2020 was a year of consequence for global health. The world's healthcare systems have been tested, exposed, and opened for critique. It is up to scholars of medicine and health—broadly construed—to do the hard work of distilling the pandemic's lessons and ensuring that policymakers take notice. WMHP is well positioned to contribute to this effort, especially by bringing together scholars and health professionals from around the world to understand what worked, what didn't, and what's required moving forward. This effort must attend to local experiences, but the response must be global.

This issue of WMHP underscores the stakes that confront us. The compilation of original research, commentaries, and book reviews in this first issue of our 13th year make clear that we must regain our focus on a wide array of pressing global health challenges, even as we continue to address the pandemic. The COVID-19 pandemic has largely occupied the political and policy arenas for the better part of a year. Meanwhile, many simmering and intensifying threats that already required our urgent attention in early 2019 and early 2020 have continued to progress. It is more important than ever we demonstrate that global health policy scholars can work on multiple tracks. We can't afford to lose another year.

The present issue of WMHP is a powerful reminder of the stakes of climate change. The sweeping findings and perspectives in these pages remind us of the local and global health consequences of climate change, and subsequently that policy responses must be simultaneously local, national, and international. At the same time, as we respond to climate change and call for action, it's important we be as inclusive as possible. As the present issue makes clear, scholarship must not only come from climate scientists, but must include clinicians, activists, scholars of the medical and health humanities, political scientists, and beyond. The conversation requires broad regional diversity as well as attention to differently placed populations within those regions. All of this, ultimately, must reach policymakers. WMHP, with its eclectic readership and commitment to interdisciplinarity, is a hospitable forum for pull together the different threads of these often qualitatively different conversations. The key is to make sure the important findings and arguments in these pages are read as widely as possible.

Thanks to the diligence and dedication of my predecessor, Dr. Bonnie Stabile, *World Medical & Health Policy* has grown leaps and bounds over the past few years.



doi: 10.1002/wmh3.414

Most of the manuscripts in this issue were curated and processed by Bonnie's team, so the lion's share of credit goes to them for their great work, for which we are grateful. We would also like to acknowledge the assistance of Clarisse Delorme, Senior Policy Advisor at the World Medical Association, as well as the World Medical Association generally, for helping to circulate the call for papers that made this issue possible.

I am pleased that we have been able to bring together a new WMHP editorial team to continue to care for and grow the journal. Cynthia Golembeski and Tyler Prochnow have joined us as Associate Editors. With the addition of Tyler and Cynthia, who bring their skill and a passion for this work, we are poised to increase our efficiency in processing manuscripts, but also to expand the journal's global reach and connectivity. In addition to serving as Associate Editor, Cynthia will continue to serve as Book Review Editor. Finally, we are excited that Gabriel Benavidez has joined WMHP as Social Media Editor. As academic publishing continues to adjust to the times, WMHP is committed to expanding the reach of the scholarship we publish, and social media is critical to that work. I'm excited to have such a great team in place as we head into WMHP's next phase. We thank the Policy Studies Organization for entrusting us with the journal.

World Medical and Health Policy

# Driving Climate and Health Solutions by Building a Collective Impact Culture

**Surili Sutaria Patel**

*The inextricable links between climate change and public health are everywhere. The climate crisis is a set of complex conditions that call for urgent action. A collective impact model offers opportunities to achieve new ways of thinking about multi-pronged climate solutions that benefit health outcomes. There lies an untapped potential to make a collective and lasting impact on climate change and equity health impact. There are five conditions that, when combined, can offer a recipe for collective success: (i) shared vision for social justice change; (ii) mutual trust and reliability through open communications between groups; (iii) coordinated activities across sectors and group types that strive to advance common goals; (iv) efforts to ensure consistent data collection and reporting on activities, as well as accountability; and (v) a separate entity designated to ensure the success of the collective. Ultimately, the process becomes the solution to future climate challenges.*

**KEY WORDS:** climate change, health equity, collective impact

## Introduction

Equated to the Indian parable of the Six Blind Men and the Elephant, climate change is the unfamiliar animal that is best understood by a company of experts in a variety of areas working collectively. In the parable, six blind men were curious to encounter an elephant in their village, something none of them had experienced firsthand before.

Each touched the part of the elephant that was before him and described to the others what he thought was true based on his own experience. The first man approached the elephant from the side and decided an elephant was as sturdy as a wall. The second man stumbled onto the trunk and determined the elephant was like a serpent. The third man touched the tail and described the elephant as a rope. The fourth man felt the tusk and believed an elephant is a spear. The fifth man climbed up to the ear and decided the elephant was a fan. And the sixth man touched one of its four legs and said it was like a tree.





doi: 10.1002/wmh3.418

Each man was committed to his own discovery and unable to fathom or trust what the others claimed. Although each subjective experience was true, the men were unable to grasp the whole truth: they were all describing the same elephant.

The climate crisis creates similarly complex conditions; and these conditions add up to the same thing—the need for immediate action. No one sector or group can take responsibility for causing climate change, and no one entity can take responsibility for solving the crisis. Every sector, every group, every player has a part to play that is important and distinct, and all must work collectively toward a solution.

All players understand their link to climate change and how they can identify the solutions for the problem before them. But various actors from across sectors, governments, communities, and more must come together and appreciate that there are different parts of the climate change and health equity challenges that make up the whole. Only then will they gain a complete picture of the climate problem. When the full truth is realized, an impartial solution will follow.

### *Health Inequities and Climate Change*

The urgency to act on climate change lies in the inextricable links between climate change and public health. The 2019 Lancet Countdown: Tracking Progress on Health and Climate Change Report proclaims that every child born today will be impacted by climate change in their lifetime (Watts et al., 2019). Changes in the climate causing extreme heat, flooding, drought, wildfires, and severe storms can be harmful to human health through increased occurrences of allergens, infectious or zoonotic diseases, injury from flooding or mold, respiratory and cardiovascular disease, food and water safety, and security, mental health challenges, to name a few (Rudolph & Harrison, 2016).

Furthermore, climate change intensifies health inequities. Some climate-sensitive communities face an unfair burden of the health impacts of climate change, including low-income communities, communities of color, native and tribal communities, pregnant people, the very young and very old, those with impaired mobility or cognition, and those with preexisting chronic illnesses (American Public Health Association [APHA], 2018a, 2018b; Rudolph, Harrison, Buckley, & North, 2018).

Climate change has disproportionate impacts on women and girls. Climate impacts on women are compounded by existing biases within many of the institutions tasked with providing development and adaptation support (United Nations, 2017). Current solutions to adapt to and mitigate climate change have promising outcomes for human health. Yet, the solutions remain insufficient if they neglect to address the disproportionate burden on certain climate-sensitive populations, as well as their limited access to the decision-making process for climate action.

## Creating a Collective Impact

### *The Optimism Behind Collective Success*

According to a Global Commission on Adaptation report, there is a need for a three-pronged revolution to realize an alternative climate future: a revolution in understanding, a revolution in planning, and a revolution in finance (Global Commission on Adaptation, 2019). These achievements are limited by those involved. Thus, a collective approach with experts and leaders in a variety of disciplines can bring about the revolution needed.

A collective impact model offers opportunities to achieve innovative ways of thinking about multi-pronged climate solutions that equitably benefit health outcomes. Entities banding together can focus on building a baseline understanding of how climate change can impact human health without sounding alarmist or political.

The collaborative can focus on adaptation and mitigation measures to improve the lives of all, and not just those who can afford the change necessary to protect lives. All can be ensured the climate-healthy choice is the easy and accessible choice.

Lastly, collective power means having the influence to persuade climate financers to dig into their deep pockets to invest in lasting social change. There lies an untapped potential to make a collective and lasting impact on climate change and equity health impact.

### *Pre-Conditions of Collective Impact*

Social innovators John Kania & Mark Kramer (2011) were the first to describe five conditions of collective success, in a 2011 *Stanford Social Innovation Review* article, that can be applied, albeit in a slightly different order, to the climate change and health equity enigma.

There are some obvious pre-steps, like engaging influential entities early on and securing financing (Hanleybrown, Kania, & Kramer, 2012). Requiring more time and effort is the climate change and health equity collaboration's full understanding of who needs to be at the table.

A variety of sectors play a role in addressing the human health effects of climate change. Most of them can also be part of the solution. These sectors include, but are not limited to, agriculture and food service, healthcare systems, finance, energy, transportation, and land use.

Additionally, community groups disproportionately impacted by climate change offer great insight into the challenges they face and culturally sensitive solutions that need adequate attention, funding, and progress. Such groups—environmental justice communities, indigenous and tribal communities, communities of color burdened by compounding climate factors, the homeless and imprisoned, to name a few—should be offered a seat at the table because of their role as trusted messengers in their respective communities and the invaluable lived experience brought to the overall discourse.

A limitation, often, is financing participation. The collective should design a way to ensure equitable participation by all parties so that the solution is as diverse as the problem. By covering the costs to travel and stay at the location of the meeting, childcare experience, days off of work, for example, can help all participants focus on the discussions and networking necessary for the collaboration to succeed.

### *Applying Five Conditions of Collective Success*

1. Align entities with a shared vision for social justice change.

To envision change, it is critical to first name the problem: racial and environmental injustices facing communities of color and low-income communities for generations created by a carbon-based economy. Only then can the collective work backward to identify the social, environmental, and economic imperatives necessary to achieve change at this scale.

According to the 2019 Global Commission on Adaptation, the world needs to see these three imperatives come to life in order to accelerate climate change adaptation to improve the lives of all.

- The human imperative focuses on minimizing the widening gap between people of wealth and people living in poverty. It notes that we will not succeed in our efforts if we aim for a reality where only some can adapt to the health impacts of climate change and others cannot.
- The environmental imperative focuses on the intrinsic connection between humans and the environment. It describes the urgent need to build resilience and mitigate climate risks to slow the devastating impacts of climate change.
- The economic imperative makes a sensible argument that the return on investments will far outweigh the costs of not acting.

Climate adaptation, when done well with urgency, innovation, and at scale, can reduce inequities and protect human health (Global Commission on Adaptation, 2019).

2. Build and maintain mutual trust through open communications.

This step may take the longest, as trust is not built overnight. Moreover, large environmental organizations or governmental agencies, and community groups have a long history of distrust. Due to the cultural, political, economic, and social justice contexts in which communities operate, it is important to address these topics directly and early on to ensure trust-building (Wolff, 2016).

For example, the Equitable and Just National Climate Platform[1] brings together environmental justice groups with national, environmental organizations to support progress toward building trust and collaboration between partners. The Climate Platform aims its efforts toward the 2020 presidential election so that the groups involved can work together to introduce equitable climate and energy policy concepts into the national discourse. At the launch of their initiative, each signatory had a basic understanding that progress toward an equitable climate future was not possible without the voices of the community groups most impacted by climate change.

3. Coordinate activities to advance the common goal.

Although the intention to collaborate is genuine, there is also a reality in which the costs of participating are a limiting factor. This is one of the reasons many collaborations result in, and not begin with, networking and peer-to-peer learning (Easterling, 2013). It is important that funding is available and equitably distributed so that the right entities can afford to have a seat at the table.

Once past the financing issues, the entities involved must agree upon activities that are both mutually reinforcing and complementary to achieve the same overarching goals and values. According to Kania and Kramer, "collective impact initiatives depend on a diverse group of stakeholders working together, not by requiring that all participants do the same thing, but by encouraging each participant to undertake the specific set of activities at which it excels in a way that supports and is coordinated with the actions of others" (Kania & Kramer, 2011).

In the instance of climate change and health equity, the players involved inherently have different activities and target audiences. For instance, a city planner may work on integrating smart surfaces (reflective, porous, and green)[2] to reduce heat island effects and enhance health, comfort, and livability in low-income urban settings. Meanwhile, a pediatrician may focus on educating parents of young children on how to manage asthma symptoms in a complex climate wrought with extreme heat, longer allergy seasons, and close proximity to a major highway. Although each works to protect the health of those disproportionately affected, they approach the situation through a vastly different lens.

4. Agree on how to define and measure success.

Social change success cannot take place overnight or over the course of one grant cycle by one entity. It, at minimum, requires collective and concurrent short-

[1]For more on the Just and Equitable National Climate Platform, visit: https://ajustclimate.org/index.html.

[2]For illustration of smart surfaces see here: https://smartsurfacescoalition.org/smart-surfaces.

and long-term efforts. The collective is responsible for defining what success looks like and how to measure progress toward the end goals.

Success does not always appear in quantitative data, but rather in qualitative or anecdotal evidence too. This is where the wisdom of community perspectives, or that of Traditional Ecological Knowledge in indigenous groups (U.S. Fish & Wildlife Service, 2011), plays an important role in the collaboration.

For example, according to an American Public Health Association report on *Priorities in Tribal Health*, Alaskan communities have witnessed changes in the weather patterns and warming of the waters, causing fish and wildlife to migrate for survival. Yet, Native American hunting and fishing rights, limited by treaty right boundaries, can restrict access to culturally important species (Wolff, 2016).

For thousands of years, subsistence lifestyles and cultural practices relied on knowledge passed down for thousands of years on the interconnectedness of humans and the environment. The Traditional Ecological Knowledge, while not quantifiable, offers wisdom dating farther back than modern approaches. Traditional methods are important ways to help tribal communities identify food substitutions and adjust hunting or fishing practices and cycles to survive a way of life passed down for generations (Wolff, 2016).

Kania and Kramer recommend undertaking the more extensive developmental evaluation, rather than the conventional evaluation process that looks introspectively at each organization's progress. The focus of a developmental evaluation is on the relationships between the entities to examine progress over shorter intervals so that challenges in activities or progress can be addressed quickly. By definition, a developmental evaluation is more nimble and appropriate for such a complex collaborative body of work (Kania & Kramer, 2013).

5. Establish a dedicated entity to ensure the success of the collective.

The concept of a hub, or a separate entity, is to manage the various pieces, players, and outputs (Kania & Kramer, 2011). The hub is essential, but not limited, to the following actions:

- follows progress of shared goals,
- keeps entities accountable,
- tracks finances,
- provides strong cohesive messaging,
- facilitates trust across all entities and fields, and
- creates a culture of innovation.

This is a gargantuan task and must be the moral guiding light for the collective effort. The hub must remain focused on the interest of the overarching goal, so as not to influence interactions among the entities or corrupt the agreed-upon messaging of the group.

*The Cautionary Tale Behind the Collective Impact Model*

With such momentum and excitement to make a change, the intentions could be unselfish in nature. However, all actions have unintended consequences that need to be examined and addressed immediately. For example, building a new park and other public spaces to reduce heat in a low-income community could inadvertently drive up the cost of housing and push out those who already live there. Additionally, it is fundamental that communities exercise self-determination in order to preserve identity and culture (Rudolph & Harrison, 2016).

## Conclusion

Kania and Kramer argue that the collective impact model should not be regarded as a five-step process, but rather as a means to leverage the collective power and wisdom of multiple entities. Also, the collaborative should remain agile with rapid learning through trial and error, to offer immediate action that is concurrent and unified by all parties involved (Kania & Kramer, 2013).

Ultimately, the collective impact process becomes the solution to future climate challenges by offering the foundation for a shared vision and mutual trust. However, if shared values are not upheld or the naming of the problem becomes the problem, as with the Indian parable, then the collaborative is at risk. It is equally important to recognize that some entities within the collaboration that have access to money and power, and this access must not play a role in their influence over the collective. Additionally, community groups should be encouraged to use their lived experience and wisdom to determine the interventions most suitable for their community or sector.

The backbone for collaboration at the size and scale needed to combat the health inequities of climate change might take time to build; however, in the interest of saving lives needs to occur as promptly as possible. If done the right way, the effort will feed the future of progress for generations to come.

## Notes

The views expressed in this commentary are those of the author and do not necessarily represent the position of the American Public Health Association.

Conflicts of interest: None declared.

**Corresponding author**: Surili Sutaria Patel, Surili.Sutaria@gmail.com

**Surili Sutaria Patel, MS**, is the director for Climate, Health and Equity at the American Public Health Association.

## References

American Public Health Association (APHA). 2018a. *Adaptation in Action Part II: Updated Grantee Success Stories from CDC's Climate and Health Program*, Washington, DC: American Public Health Association. https://www.apha.org/-/media/files/pdf/topics/climate/adaptation_in_action_part_2. Accessed April 1, 2020.

American Public Health Association (APHA). 2018b. *Priorities in Tribal Public Health*, Washington, DC: American Public Health Association. https://apha.org/-/media/files/pdf/topics/environment/partners/tpeh/priorities_tribal_health_2018. Accessed April 3, 2020.

Easterling, Douglas. 2013. "Getting to Collective Impact: How Funders Can Contribute Over the Life Course of the Work." *The Foundation Review* 5 (2): 67–83. https://doi.org/10.9707/1944-5660.1157

Global Commission on Adaptation. 2019. *Adapt Now: A Global Call for Leadership on Climate Resilience*, Global Center on Adaptation and World Resources Institute. Wake Forest School of Medicine, North Carolina, USA. https://cdn.gca.org/assets/2019-09/GlobalCommission_Report_FINAL.pdf. Accessed April 3, 2020.

Hanleybrown, Fay, John Kania, and Mark Kramer. 2012. "Channeling Change: Making Collective Impact Work." *Stanford Social Innovation Review*. https://ssir.org/articles/entry/channeling_change_making_collective_impact_work. Accessed March 29, 2020.

Kania, John, and Mark Kramer. 2011. "Collective Impact." *Stanford Social Innovation Review*. https://ssir.org/articles/entry/collective_impact#. Accessed March 29, 2020.

———. 2013. "Embracing Emergence: How Collective Impact Addresses Complexity." *Stanford Social Innovation Review*. https://ssir.org/articles/entry/social_progress_through_collective_impact. Accessed March 29, 2020.

Rudolph, Linda, Catherine Harrison, Laura Buckley, and Savannah North. 2018. *Climate Change, Health, and Equity: A Guide for Local Health Departments*, Oakland, CA and Washington, DC: Public Health Institute and American Public Health Association. https://www.apha.org/-/media/files/pdf/topics/climate/climate_health_equity.ashx. Accessed April 1, 2020.

Rudolph, Linda, and Catherine Harrison. 2016. *A Physician's Guide to Climate Change, Health and Equity*, Oakland, CA: Public Health Institute. https://climatehealthconnect.org/resources/physicians-guide-climate-change-health-equity. Accessed March 30, 2020.

United Nations Department of Economic and Social Affairs. 2017. *Climate Change and Social Inequality*. Working Paper No. 152. New York, NY: United National Secretariat. https://www.un.org/esa/desa/papers/2017/wp152_2017.pdf

United States Fish & Wildlife Service. 2011. *Traditional Ecological Knowledge for application by Service Scientists* [Online]. https://www.fws.gov/nativeamerican/pdf/tek-fact-sheet.pdf. Accessed April 3, 2020.

Watts, Nick, Markus Amann, Nigel Arnell, Sonja Ayeb-Karlsson, Kristine Belesova, Maxwell Boykoff, Peter Byass et al. 2019. "The 2019 Report of The Lancet Countdown on Health and Climate Change: Ensuring That the Health of a Child Born Today is Not Defined by a Changing Climate." *The Lancet*. 394(10211), 1836–1878. https://doi.org/10.1016/S0140-6736(19)32596-6

Wolff, Tom. 2016. "Ten Places Where Collective Impact Gets It Wrong. Global Journal of Community Psychology Practice." *Global Journal of Community Psychology Practice* 7 (1): 1–11. https://www.gjcpp.org/en/resource.php?issue=21&resource=200. Accessed March 29, 2020.

World Medical and Health Policy



# Climate Change and Public Health in India: The 2018 Kerala Floods

**Anil Varughese and Chithra Purushothaman**

*Kerala is one of India's most vulnerable states in India when it comes to climate-induced disasters. Kerala's public health department grappled with a flood of unprecedented magnitude in August 2018. Situating the flood in the context of Kerala's state and society, this paper addresses three questions: What was the level of flood-prevention preparedness? What were the public health effects and how were they managed? Finally, what policy lessons were learned? Drawing from reports of relevant national and state agencies responsible for disaster management as well as first-hand accounts of nongovernmental organizations and media coverage, this paper argues that while Kerala's flood-prevention preparedness was far from ideal, its postflood response in mounting a rapid and effective rescue and relief operation as well as in preventing a public health crisis was commendable. The paper also shows that impressive achievements in climate-disaster health management can be achieved through a decentralized and participatory public health system in which coordinated public action is managed by a capacious state with the active collaboration of civil society.*

**KEY WORDS:** 2018 Kerala floods, climate change, disaster management, India, public health

## Introduction

Floods have been widely reported to be one of the most common natural disasters induced by climate change (Akhtar, 2020; WHO, 2009). While floods are caused by a combination of weather and human factors, there is increasing consensus that there are clear and conspicuous ways in which anthropogenic warming of the climate system increases flood risks, particularly the risk of flash floods. Caused by heavy torrential downpour over a short period of time, flash floods are more dangerous and destructive to human health and well-being than any other extreme weather event due to their speed and unpredictability. The latest report of the Intergovernmental Panel on Climate Change (IPCC, 2018), based on the assessment of over 6000 peer-reviewed recent publications, notes that a rise in global mean temperature of 1.5°C from pre-industrial levels will result in increased frequency, intensity, and/or quantity of heavy precipitation, with an associated risk of flood hazards in several regions of the world (IPCC, 2018).

South Asia, home to one-fifth of the world's population, is one of the regions projected to experience an increase in climate-induced hydrological disasters (IPCC, 2014). India is one of the most flood-prone countries in the world, with powerful monsoon (rain) seasons, silted river systems, and steep mountains.



doi: 10.1002/wmh3.429

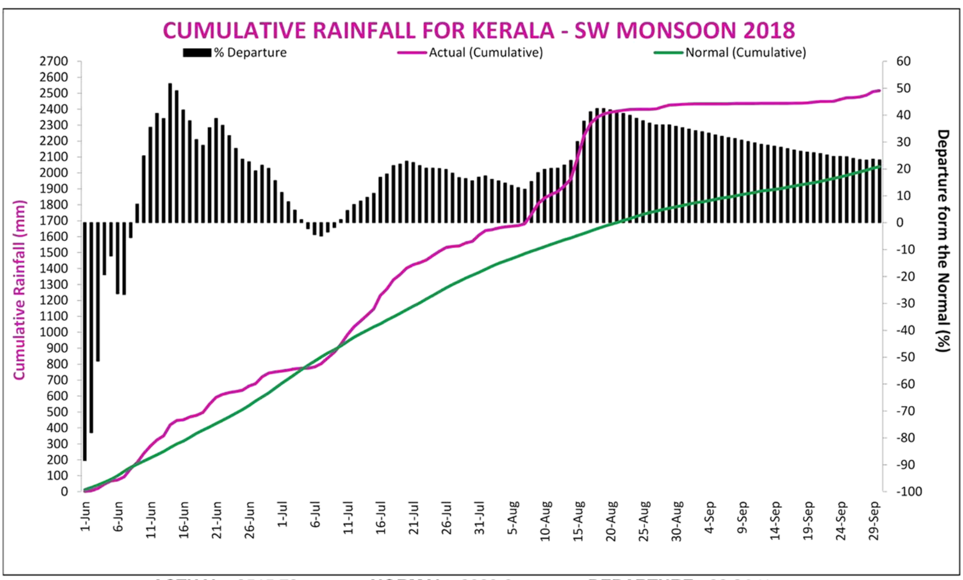
The Indo-Gangetic plains, an extensive river delta comprising of northern and eastern India's fertile lands—accounting for approximately 50 percent of the country's total agricultural production—has historically been prone to flooding. The frequency and intensity of floods have, however, increased in the recent past due to the melting of Himalayan glaciers (Krishnan et al., 2020). Among Indian states, Assam (2012), Uttarakhand (2013), Kashmir (2014), Tamil Nadu (2015), and Kerala (2018) experienced catastrophic floods in the last decade. Frequent tropical cyclones and associated floods are common in the coastal state of Andhra Pradesh (Nageswara Rao et al., 2008). Several other states are prone to annual flooding as well. India's average temperature is projected to rise by approximately 4.4°C by the end of the 21st century compared with the 0.7°C increase between 1901 and 2018 (Krishnan et al., 2020). This overall increase in surface temperature is expected to result in more frequent floods and other extreme weather events in different regions of the country.

Among India's cities, as many as 78 are vulnerable to flooding (Pandey, 2018). India's two largest cities, Delhi and Mumbai, are flooded almost every monsoon season, creating chaos and misery for millions. Kolkata, another metropolis of India, has been identified as one of the world's most flood-prone coastal cities (Balica et al., 2012). Even though climatic factors make these heavily populated cities highly vulnerable, anthropogenic factors, including lack of urban planning, reduced green cover, encroachment of flood plains, clogged river systems, inadequate drainage and sewage, and unsustainable land-use practices, have made them susceptible to frequent flooding (Dhiman et al., 2019).

It is difficult to attribute extreme weather events exclusively to anthropogenic climate change. However, adequate evidence is now available for more frequent incidence of extreme weather events, such as floods and droughts, which goes beyond the range of natural climate variability. Research shows that human activity, including fossil fuel burning, carbon emissions, and deforestation, is warming the earth at an unprecedented rate (IPCC, 2018). Warmer temperatures alter the intensity, frequency, and seasonality of climate patterns and precipitation levels as a warming atmosphere holds more water vapor. Changes and variability in atmospheric moisture content lead to a complex set of weather outcomes—erratic rainfall, drought, and an increase in heavy spells of rain during shorter durations (Abhilash, 2019). Indian monsoon has been shown to follow this pattern of becoming more erratic with an increased likelihood of flash floods (IPCC, 2014). The Kerala flood can thus be understood as a climate change-induced natural disaster (Abhilash, 2019).

The long-term effects of floods on human health are not well understood due to lack of systematic data, but, in the short term, they have been found to produce major negative consequences (Alderman et al., 2012; Colwell, 2006; IPCC, 2014, 2018; Saulnier et al., 2017; St. Louis & Hess, 2008). Flooding poses significant public health risks as it increases the rate and spread of water-borne diseases, such as diarrhea, cholera, hepatitis E, leptospirosis, and other gastrointestinal infections (Alderman et al., 2012); vector-borne diseases, such as malaria and dengue fever (Semenza & Suk, 2018); and respiratory and allergic diseases, such as asthma and skin rashes (Mendell et al., 2011; Rose & Akpinar-Elci, 2015). Stagnant water and increased precipitation produce breeding grounds for mosquitoes, bacteria, viruses, and other microorganisms like mold (Gage et al., 2008; Patz et al., 2005), increased susceptibility to infectious diseases or pandemic outbreaks, and higher levels of morbidity and mortality. Exposure to sewer water and other toxic waste increases the chances of cancers and kidney/liver diseases (EPA, 2018). These health risks are interlinked with mental health conditions such as depression, stress, and anxiety, which exacerbate physical illnesses (Akpinar-Elci et al., 2018; Bei et al., 2013). The above health impacts, combined with their economic costs, large-scale displacement, and infrastructure disruption, can contribute to a significant reduction in the overall quality of life of affected populations (Sekulova & Van den Bergh, 2016).

Against this background, the health impacts of climate change-induced flash flooding in the southern Indian state of Kerala are studied here. Kerala experienced what was reported to be the worst natural disaster in a century in August 2018, receiving unusually high rainfall in a short period of time during the southwest monsoon season (Venkatesh & Kuttappan, 2018). Between 1 June 2018 and 19 August 2018, Kerala received 2346.6 mm of rainfall instead of the expected 1649.5 mm, a 42 percent excess (see Figure 1). In the month of August alone, the state received 96 percent excess rain [821mm actual rain in place of the expected 419mm] (KSDMA, 2018), turning its streets into rivers. This unusual amount of torrential rain in a short span of time resulted in the saturation of top soil, powerful surface and river overflows, deep landslides, and soil erosion, causing substantial loss of human life, livelihoods, property, and infrastructure. More than 5.4 million people were affected, 1.4 million of whom were displaced from their homes; a large proportion of them were sheltered in over 3200 relief camps across




ACTUAL= 2515.73 mm NORMAL= 2039.6 mm DEPARTURE= 23.34 %

Figure 1 Performance of Southwest Monsoon over Kerala from June 1, 2018 to September 30, 2018. *Source*: Indian Meteorological Department, Government of India, Thiruvananthapuram (https://www.imdtvm.gov.in).

the state (Rebuild Kerala, 2018). Nearly 498 people lost their lives. Over 20,000 houses and 10,000 km of roads were damaged. Total loss from the damage inundating 65,000 hectares of land and 32,000 hectares of crops was pegged at around $5 billion US dollars, more than the annual outlay of the state, which was about $3.5 billion USD in 2017–18 (*Indian Express*, 2018; Rajiv, 2018).

Situating the study of the 2018 floods in the context of Kerala's state and society, this research addresses three questions. First, where did Kerala stand in terms of flood-prevention preparedness prior to the 2018 disaster? Second, what were the specific health impacts of the 2018 floods and what did observers conclude about the management of health impacts? Finally, what policy lessons have been learned and what recommendations can be made from this case study? To address these questions, data is primarily drawn from reports of relevant national and state agencies responsible for disaster prevention, management, and reconstruction, including Central Relief Commissioner, Indian Meteorological Department, Central Water Commission, National Disaster Management Authority (NDMA), Ministry of Health, Rebuild Kerala, Kerala State Disaster Management Authority (KSDMA), Local Self Government Department, National Database for Emergency Management (NDEM), Kerala State Spatial Data Infrastructure (KSDI), as well as reports and first-hand accounts from nongovernmental organizations and live coverage of the floods and postflood reporting in Indian media during August–September 2018. Along with a large number of citizens and civil society organizations, local news channels and news reporters were actively engaged in helping manage this public health emergency by identifying those in need and getting people to safety.

## Kerala

Kerala, with a population of roughly 35 million, is highly vulnerable to climate-induced natural disasters due to its peculiar geography (sandwiched between the sea coast and the steep mountain slopes of Western Ghats), climatic conditions (high-intensity rainy seasons), and high population density. Kerala is prone to 39 types of known natural hazards, as identified by the State Disaster Management Authority, of which flooding is one of the most common (KSDMA, 2016a). About 15 percent of Kerala's land and eight million people are vulnerable to flooding (KSDMA, 2011).

One of the key risk factors in Kerala's climatic phenomena is two strong rainy seasons. The southwest monsoon (*edavapathi*) hits the state between June and September. The northeast (*thulam*) monsoon arrives between mid-October and December. The more powerful southwest monsoon accounts for over 80 percent of Kerala's total annual rainfall of 3000 mm, in a span of 4 months. This climatic pattern of heavy rains within a short span of time and the presence of low-lying areas along the coastal region make floods the most common natural disaster for Kerala (Rebuild Kerala, 2018; Shaji, 2019). Landslides, sea-level rise, coastal erosion, and droughts are flood-related risks, endangering Kerala's high biodiversity and fragile ecology. Given this backdrop, the predicted global patterns of increased frequency and severity of sporadic but concentrated spells of unusually heavy rain, resulting in flash floods, droughts, and mudflows are an ominous forecast for Kerala (IPCC, 2014, 2018).

Kerala has been widely acclaimed for its achievements in a wide variety of human and social development indicators despite low per capita income. Its health outcomes, in particular, are on par with developed countries. Life expectancy is 75 years compared with 78 years in the United States, while the average for the rest of India is 69 years (CBHI, 2019). In the Human Development Index, Kerala consistently outperforms other Indian states. The National Health Index, a weighted composite index based on 23 indicators covering key aspects of health outcomes, governance, infrastructure, and service delivery, labels Kerala as a "frontrunner" and ranks Kerala at the top of 21 Indian states (NITI Aayog, 2018, 2019). Kerala has already achieved the Sustainable Development Goal (SDG) targets for the year 2030 in the areas of neonatal mortality (12 deaths per 1,000 live births) and under-five mortality (25 deaths per 1,000 live births) (NITI Aayog, 2019). Literacy is another factor that is relevant to health outcomes. Female adult literacy is 92 percent in Kerala compared with the Indian average of 65 percent (CBHI, 2018). These data are summarized in Table 1.

Kerala's success on the health indicators shown in Table 1 is attributed to a number of factors, including the state's longstanding egalitarian ethos, history of social movements, high levels of literacy, and demand-driven public intervention. Governmental support for an organized public healthcare system, propelled by a concern for the well-being of all sections of the society, has had a long track record in Kerala. Long before the arrival of Western medicine in the 18th century, an indigenous strand of medicine (*Ayurveda*) was practiced in Kerala. Diagnosis and treatments using herbs were performed by locally trained *vaidyans* (Ayurveda healers); the training of Ayurveda was passed on from one generation to another by witnessing treatments. The dynasties that ruled the erstwhile princely states that later formed contemporary Kerala supported the codification of Ayurveda treatment procedures and the establishment of Ayurveda medical colleges starting in the mid-19th century (Kannan & Frenz, 2019). The practice of Ayurveda created a tradition of seeking care from a trained professional (Nabae, 2003). When traditional medicine was found to be ineffective against raging pandemics, such as cholera, smallpox, and

**Table 1.** Health Indicators, Kerala and India

| Indicator | India | Kerala |
|---|---|---|
| Crude birth rate | 20.2 (2017) | 14.2 (2017) |
| Crude death rate | 6.3 (2017) | 6.8 (2017) |
| Infant mortality rate (per 1,000 live births) | 34 (2016) | 10 (2016) |
| Life expectancy | 68.7 | 74.9 |
| Sex ratio (no. of females per 100 males) | 943 | 1084 |
| Literacy % (female) | 64.6 | 92.1 |
| Literacy % (male) | 80.9 | 96.1 |
| Maternal mortality rate (per 100,000 births) | 130 (2016) | 46 (2016) |
| Immunization coverage % | 62 | 82.1 |
| Per capita public expenditure on health (in nominal terms, major states) | 1,172 (2016) | Rs. 1,463 (2016) |
| Population density (per square km) | 382 | 860 |

malaria in the 19th century, local kings sought, supported, and funded the use of Western medicine, training of personnel, and establishment of free treatment centers (Kutty, 2000). Mandatory vaccination of public servants and students was announced by a royal proclamation in 1879. These steps effectively gave rise to a public healthcare system based on modern medicine, which found its institutional expression in the establishment of a public health agency in 1929 (Kumar, 2019).

The advances in the health sector were complemented by the synergistic effects of developments in other sectors. Notable among them were the expansion of access to education and the social reform movements of the late 19th century, which were later subsumed by radical political parties. Literacy and wider access to state-funded education provided improved health awareness even among poorer sections of the population. At the same time, a history of anti-caste social movements and political mobilization of poorer citizens expanded political awareness and ratcheted up demands for access to health and education. When modern Kerala was formed in 1956, a public healthcare system and a healthcare-seeking public were already in place. The election of a progressive government in 1957—Kerala's first elected government—with a legislative agenda of building a welfare state through radical social reform set the stage for modern Kerala's unique development experience as a paragon of high achievements in health and education. In the succeeding decades, political mobilization on the ground created sustained pressure on successive state governments to continue investing in healthcare and health infrastructure, regardless of their political affiliation (Kutty, 2000). Kerala's share of public spending on health averaged around 10 percent of total public spending from the 1950s to the 1990s, considerably higher than other Indian states (Jacob, 2014). Higher public spending led to better health outcomes and greater growth of health infrastructure across the state. In recent decades, the devolution of funds and functions in the healthcare sector to local self-governing councils at the panchayat and district levels have institutionalized a decentralized and collaborative healthcare delivery system, with functional differentiation among different levels of government, local ownership of health service functions, and mobilization of voluntary sector resources. This has enhanced the state government's capacity to achieve effective coordination and public participation during public health emergencies. In this new system, governments and civil society are actively involved in the planning, management, and monitoring of healthcare services (Elamon et al., 2004).

Kerala's highly competitive democratic politics plays a crucial role in sustaining this participatory public healthcare system. Politics in contemporary Kerala is dominated by two settled political fronts—the Left Democratic Front (LDF) and the United Democratic Front (UDF). The LDF is a coalition of left-leaning and secular parties led by the Communist Party of India-Marxist (CPI-M), while the UDF consists of the center-leaning Indian National Congress (INC) and other smaller parties. As a result of the stable bipolar coalition politics, political competition is high in Kerala. The combination of high political competition and politically aware citizenry makes for remarkably responsive governments and vigilant voters, compared to other Indian states. Delay, indecision, or incompetence in addressing legitimate needs, such as in the context of a natural disaster, can be costly for any ruling regime.

Kerala's public healthcare system focuses on providing basic healthcare facilities through primary healthcare centers (PHCs) in rural areas. Though the public healthcare system comprises limited secondary and tertiary care institutions in key cities, the private sector provides the majority of secondary and tertiary care institutions. The high demand for quality health infrastructure has led to the expansive growth of private healthcare institutions since the mid-1980s. The growth of private health facilities has helped Kerala meet the surging demand for quality health care (PHCPI, 2020). Yet, it has not resulted in the gradual deterioration and irrelevance of the public sector, as could be expected when medical care is exposed to market forces. In addition, private sector growth is directly linked to the long-term virtuous effects of developments in the public sector, such as the creation of high levels of health awareness, demand for quality health care, and training of competent personnel (Kutty, 2000). The public health system is responsible for the control of health emergencies in strategic coordination with the private sector.

Decades of progressive social policy and public action have thus enabled affordable and quality public health care in Kerala. Public action, which includes the actions of the state as well as a variety of nonstate actors, has helped to improve the health and educational well-being of Kerala's citizens (Dreze & Sen, 1989; Ramakumar, 2006). State support for health care and health infrastructure development has been a crucial factor in the health achievements of Kerala, despite the presence and recent growth of private health facilities (Isaac & Sadanandan, 2020; Kutty, 2000).

The aforementioned characteristics of Kerala's health system helped the state to quickly intervene and overcome the flood-related health crisis in 2018. Kerala's management of flood-related public health challenges is a testament to the importance of an effective public health system for disaster management (Wallemacq & de Almeida, 2018). The outbreak of the Nipah virus in May 2018 tested the waters initially, posing the question of whether Kerala could contain a public health emergency within days (WHO, 2018). Even though this highly infectious zoonotic disease killed 18 people in North Kerala, the state machinery's swift action contained the infection before it could become a pandemic. Timely diagnosis, strict adherence to infection-control protocols (physical isolation, contact tracing, setting up quarantine clinics), and proper communication (issuing regular alerts to the public on precautions and creating awareness) helped in containing the virus quickly. In 2019, even though one case of Nipah was reported, it was successfully brought under control without community transmission. This experience in tackling Nipah helped Kerala in swiftly adopting necessary control and prevention protocols during COVID-19, as India's first coronavirus cases were reported in Kerala. The key role of the public healthcare system is also evident in Kerala's ongoing, and by all indications, efficient tackling of COVID-19 in 2020 (Faleiro, 2020).

## Flood Preparedness

Despite the achievements of the Kerala model of development, available data shows that Kerala was far from prepared to manage a disaster of the magnitude of the 2018 floods. A combination of short-term and long-term factors points to the unplanned nature in which government agencies responsible for disaster management handled available warnings and response time. First, reports from the disaster management authority of the state (KSDMA, 2018) show a wide discrepancy between the amount of rainfall forecasted by the Meteorological Department of India (IMD), the nodal national agency for forecasting, and the actual received rainfall. The flood forecasting and warning system are supposed to alert the state government well in advance of the arrival of floods, to enable mobilization of resources, and to facilitate the movement of people and property to safer grounds. In the case of the 2018 floods, data shows that the rainfall forecast received by the state authorities was consistently below the actual rainfall for months. The possibility for excess rainfall was as low as 3–13 percent in the forecast (KSDMA, 2018). Nonetheless, repeated meetings were convened by the State Relief Commissioner with all stakeholders starting in May 2018 to work on better preparedness in all districts and concerned departments. These meeting reports were regularly reviewed by the Chief Minister and other ministers, but they seem to have been completely unaware of the severity of the impending floods (KSDMA, 2018). The forecasting of the spatial distribution and intensity of rainfall, and the early warning detection systems did not work as expected. The disaster management system failed to predict the flood and allow adequate time to mount a preventive response.

The second factor that points to inadequate preparedness has to do with the inept management of dams, especially the timely release of water from overfull dams, maintained by the Kerala State Electricity Board (KSEB) and the Water Resources Department. A total of 39 dams had reached their full capacity by the end of July 2018, but the water was not released from the dams in a slow and staggered manner to allow for adequate absorption capacity downstream. Instead, dams were kept full, purportedly with the goal of conserving maximum water for hydroelectrical power generation, until a point was reached where the dams could not contain any more water. Opening the dam gates in quick succession after the groundwater aquifers had been saturated resulted in the submersion of villages and towns downstream in a matter of hours. Adequate flood cushions were also not maintained around the dams in order to absorb the water from high rainfall. It appears that dam management processes and guidelines for releasing water were not fully complied with (Thakkar, 2018). Better and more graded management of dam water would have reduced the severity of the flood.

Third, Kerala's level of preparedness was also hindered by willful neglect or lack of seriousness about environmental degradation and climate-induced risks for natural disasters. There was a collective aversion to accepting the vulnerability of Kerala, despite expert advice and scientific evidence, and to taking decisive action to prevent potential future disasters by successive governments. The Western Ghats Ecology Expert Panel (WGEEP), a national commission appointed by the Ministry of Environment and Forests to preserve the biodiversity of the Western Ghats region, had warned about impending disasters due to deforestation and changes in land-use patterns (Gadgil Commission, 2011). The Gadgil Commission (2011) report recommended careful regulation of industrial, tourist, transportation, power generation, and other "developmental" activities in the ecologically sensitive regions of Western Ghats. A second high-level working group appointed in 2013—the Kasturirangan Committee—for the same purpose also made similar, albeit less expansive, recommendations (Kasturirangan et al., 2013).

The recommendations of both committees were contested due to proposed restrictions on developmental activities and largely ignored as impractical.

The lackadaisical attitude toward environmental preservation is further demonstrated by the practice of permitting, by regulatory changes or by acquiescence, encroachments on water bodies, rivers, forests, and ecologically fragile lands for constructing buildings, sand mining, and stone quarrying, purportedly due to pressure from various economic lobbies. High demand for newer and bigger homes has resulted in construction and mining in ecologically sensitive areas. Kerala's large expatriate population, particularly from the Gulf countries, contributes a fifth of all remittances sent to India by nonresident Indians (Basheer, 2019). Remittances are largely used for consumption and other nonproductive activities, such as investments in real estate near rivers and backwaters, and construction of large homes (Kannan & Hari, 2020, Rajan, 2004, Sunny et al., 2020, Zachariah et al., 2001). Such continuous addition of unsustainable infrastructure, with scant regard to Kerala's fragile ecology, has increased Kerala's environmental footprint (Basheer, 2019; Zachariah et al., 2001). Lack of adequate ecological sensitivity, combined with climate-change effects, population growth, and unhealthy patterns of land utilization, left the state unprepared to prevent a deluge even when it had the capacity to pull together a prevention system.

## Health Impacts of the Flood

In India's federal system, the primary responsibility for undertaking rescue, relief, and rehabilitation in the event of natural disasters rests on the state governments. The State Disaster Management Authority (SDMA) coordinates the relief and rehabilitation in liaison with the National Disaster Management Authority (NDMA). Below the SDMA, the District Disaster Management Authority (DDMA) is the focal point for frontline relief and rehabilitation, assessing of needs, establishing relief camps, and providing adequate food, water, and sanitation facilities in the camps. DDMAs coordinate the relief efforts with local self-government institutions, such as panchayats, municipalities, and city corporations, which control and manage civic services, NGOs, civil society, and voluntary organizations (see Figure 2).

Even though Kerala's level of flood preparedness was far from ideal, the postflood response was commendable. The government of Kerala and Kerala Disaster Management Authority (KSDMA) quickly swung into action and mounted a rapid and effective evacuation, rescue, and relief operation followed by rehabilitation and reconstruction. The administrative machinery of the state was quickly called into coordinated action. Flood alerts were issued through all forms of media, including social media (Thiagarajan, 2018). State-level and district-level 24/7 control rooms were set up to manage the relief efforts. Relief camps were widely reported to be efficiently run, with adequate provision of food, water, and sanitary facilities. District Collectors personally ensured transparent and efficient use of resources without wastage or pilfering (Sen, 2018). The National Disaster Response Force, the Army, Air Force, and the Navy participated in rescue efforts with specialized personnel, equipment, and supplies in "one of the largest rescue missions conducted in the decade" (Sen, 2018). They airlifted people and built

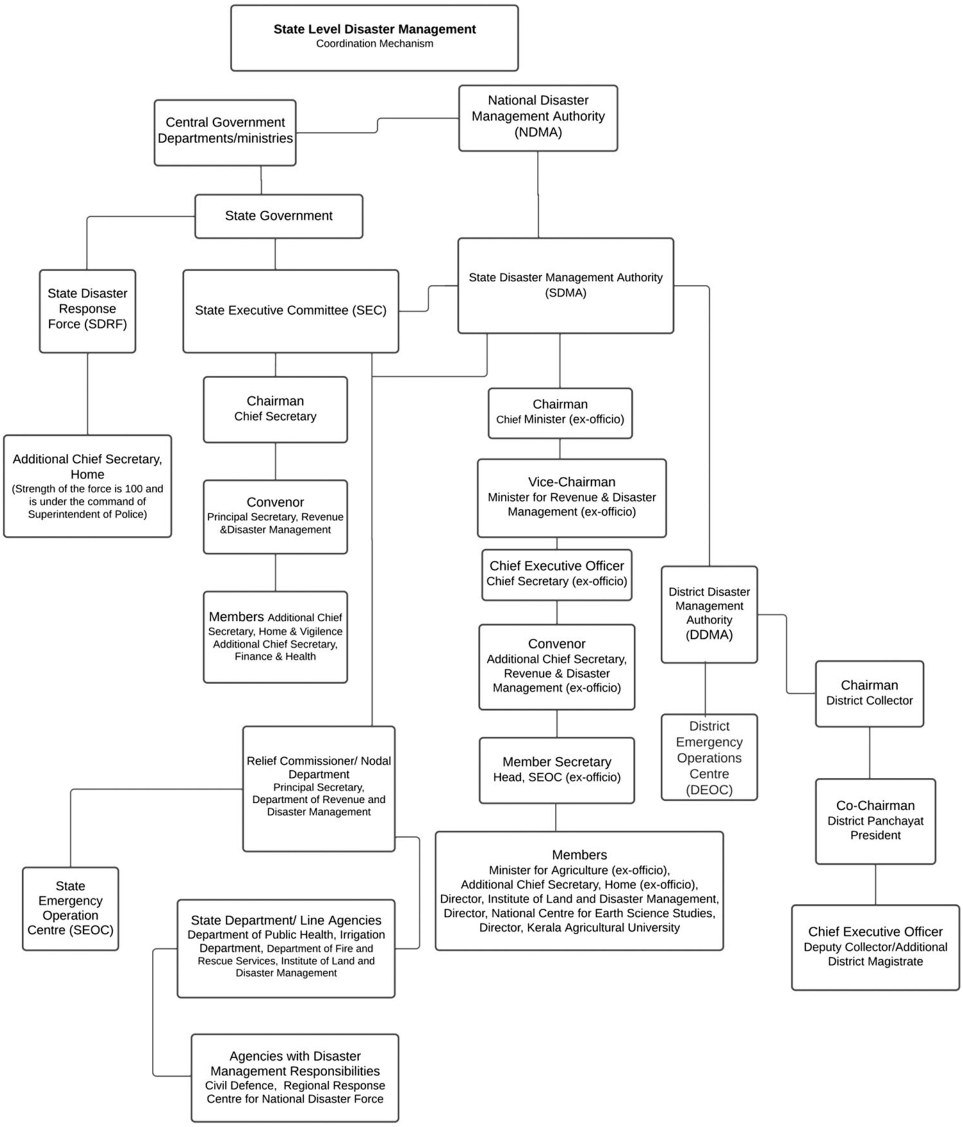



Figure 2 Kerala's State-level Disaster Management Coordination Mechanism. *Source*: KSDMA (2011, 2016b).

temporary roads and bridges for evacuation. Thousands of volunteers used social media to receive messages from family members of stranded persons and passed on the messages to control rooms and rescue teams. Innovative use of social media for disseminating information and coordinating rescue efforts was widely noted in the press coverage. The efforts of the government were heavily complemented by the citizens of Kerala, who came together in large numbers, as individuals or under the aegis of civil society organizations, to help save lives and property, and to provide specialized relief services (e.g., relocating elderly, installing bio-toilets, cleaning and sanitizing houses, etc.). On the whole, Kerala's public sector agencies and civil society were collaborative, responsive, effective, and efficient in the postflood response.

The provision of health care during the flood was coordinated by the Department of Health and Family Welfare. It established a control room in the state capital to address health-specific issues, with a mandate to ensure the availability of medically trained personnel and medicines where needed. Different teams were set up to manage different health-related tasks, with doctors as nodal officers. The team of nodal officers met multiple times daily to assess needs and to brief the health minister. This team also managed the allocation of teams of doctors and health volunteers arriving from other Indian states. The team worked through district health officials and Kerala's 1200 local self-government institutions, their staff specialists in public health and PHCs, and in close coordination with private hospitals. Thousands of volunteers from nongovernmental organizations complemented the efforts, with active participation in service delivery. A map of the state of Kerala and the districts impacted by the 2018 floods is in Figure 3.

Despite such a quick and collaborative response, the immediate health impacts were seen not only in the heavy loss of life but also in the extent of physical injuries caused by serious damage to and destruction of homes. Villagers moving on foot in contaminated water and on land through dangerous debris without any protection also resulted in injuries and infections, which must have surely numbered in the tens of thousands, but for which data is unavailable. A study of one of the most vulnerable sites, Kuttanad, which is four to ten feet below sea level, found an "abundance of pathogenic and antibiotic-resistant bacteria," including heavy amounts of "fecal contamination indicators, such as *Escherichia coli* and *Enterococcus faecalis* and multidrug-resistant strains of *Pseudomonas aeruginosa, Salmonella typhi/typhimurium, Klebsiella pneumoniae, Vibrio cholerae*" (Jaya Divakaran et al., 2019).

During the floods, several hospitals, both government-run and private, were inundated with people seeking medical care. This put tremendous pressure on the government to provide timely and proper health care to those in critical need (Devasia, 2018). In some cases, the patients had to be evacuated and moved to other hospitals. For Alappuzha district—located below sea level—mobile medical boats and water ambulances were provided to attend to the situation. Most of the relief camps were equipped with doctors and medical staff. This ensured the availability of care for those with underlying health issues. However, there were some camps that only had access to first aid. Shortages of medicine and equipment, including oxygen cylinders, were reported, though for a very short time. The state was able to quickly return to normal, mainly because of the high degree of coordination between the government, civil society, NGOs, and people.

The government had the responsibility to prevent the outbreak of epidemics, such as cholera, diarrhea, and other communicable diseases in the immediate aftermath of the floods. Public health authorities were preparing for postflood epidemic management as they were mindful of the crisis that could arise from the consumption of contaminated water. The health authorities were, to a large extent, successful in creating awareness among people about the importance of not using drinking water directly out of their open wells. The media conveyed the message

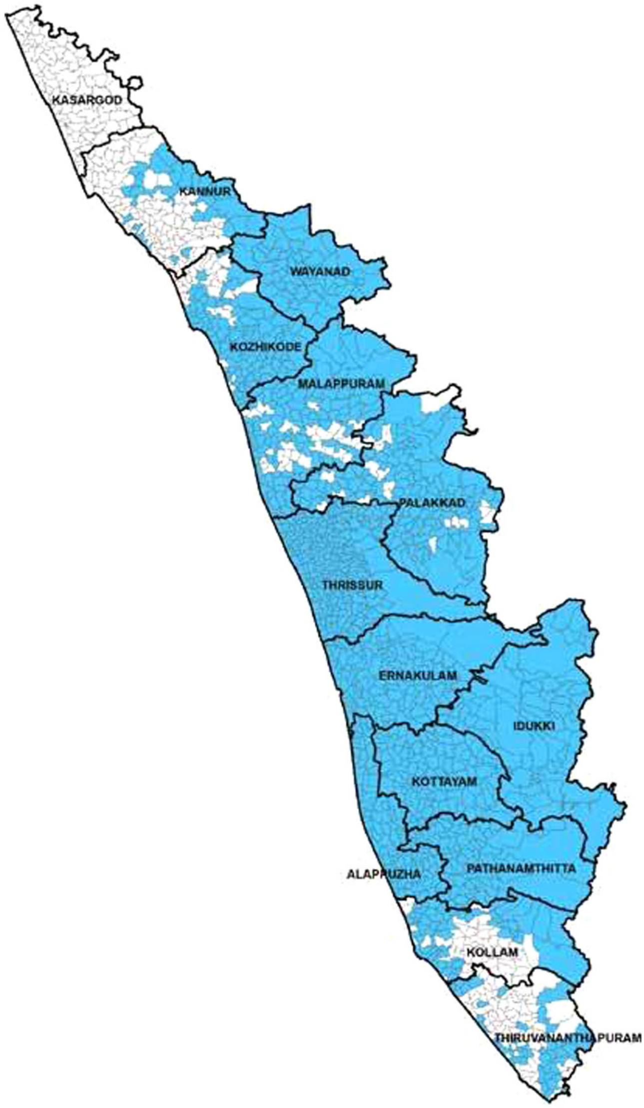



Figure 3 Kerala Districts and Villages impacted by 2018 Floods. Flood impacted areas are in blue, district boundaries in black, and taluk boundaries in gray. *Source*: Thummarukudy and Peter (2019, p. 44).

effectively so that the public could understand how to purify potable water after a flood. This helped avert a major outbreak of water-borne diseases.

Flooded areas are also breeding grounds for mosquitoes, which made it important for the health authorities to prepare for vector-borne diseases, including malaria, dengue fever, and chikungunya. However, there were very few cases reported, which shows that vector-borne diseases were also effectively controlled. In the low-lying Kuttanad region of Alappuzha district, "KoBo"—an open-source technological toolbox developed by the Harvard Humanitarian Initiative for data collection and analysis in humanitarian emergencies—was used to geotag homes and identify hotspots (Paliath, 2018). With the combined efforts of the people and the government, epidemic outbreaks were averted. Careful planning and close monitoring of health conditions in camps and available medical facilities by governmental authorities, as well as active participation by civil society at all levels, helped avoid an impending crisis.

During the rainy season, the number of leptospirosis (commonly referred to as rat fever) cases usually increases in the state. Even though the numbers were much higher in September 2018, they did not spike to epidemic levels because the health system was more or less prepared to tackle any outbreak (DHS, 2019). As a preventative measure, millions of doxycycline tablets were pro-actively given to flood victims and volunteers (Paliath, 2018). Health volunteers from community organizations were assigned to visit local homes to ensure drinking water was clean and to disseminate information about epidemic prevention. When yearly data for leptospirosis is taken into consideration, there was an increase of around 600 cases during the 2018 floods. The Directorate of Health Services' reports on communicable diseases reveal that the number of cases of leptospirosis more than doubled between August and September 2018, from 246 to 854 cases, but the number dropped to 206 by October. Leptospirosis cases numbered 1,408; 2,079; and 1,211 in the years 2017, 2018, and 2019, respectively (DHS, 2020). However, the number of deaths due to rat fever remained almost the same as in previous years, which points to the preparedness of Kerala in tackling communicable diseases.

The number of cases of communicable diseases reported for the months of August, September, and October in the years 2016, 2017, and 2018 reveals additional insights into water-borne illnesses in the aftermath of flooding. The list includes diseases with no reported cases during the flooding season, including Kyasanur forest disease, Nipah, and West Nile fever, as well as a longer list of reported cases of dengue fever, malaria, chikungunya, AES, leptospirosis, Japanese encephalitis, hepatitis A and B, cholera, diphtheria, typhoid, acute diarrhea, scrub typhus, and H1N1, though the numbers were quite small for most of these (DHS, 2019). Other than leptospirosis, the one disease that appears to have substantially increased by the August 2018 floods was acute diarrhea (DHS, 2019).

The number of cases of acute diarrhea remained high for August through October 2018, as residents initially had difficulty accessing clean water. In 2016 and 2017, the high numbers of cases in August dropped significantly by September and October. In contrast, the numbers slightly increased in September 2018 and then dropped in October 2018 (see Table 2).

Elderly persons and persons with disabilities were victims of heightened mental and physical health deterioration during the flood. Kerala has the largest proportion of senior citizens (12.6 percent above 60 years of age) and the highest old-age dependency ratio among Indian states. Many of these 4.2 million senior citizens suffer limited mobility, inadequate social support, social isolation, and chronic illnesses—there is a high incidence of diabetes, hypertension, and kidney disease—and are dependent on others. There is a larger proportion of women in this group, often without a surviving spouse. A large majority of these senior citizens live alone or with spouses but without the

**Table 2.** Incidence of Two Most Commonly Diagnosed Infectious Diseases in Kerala, Aug.–Oct. 2016–2018

| | 2016 | 2017 | 2018 |
|---|---|---|---|
| *Leptospirosis* | | | |
| Aug | 183 | 46 | 246 |
| Sept | 195 | 78 | 854 |
| Oct | 125 | 142 | 208 |
| *Acute diarrhea* | | | |
| Aug | 48,209 | 40,166 | 45,856 |
| Sept | 29,616 | 31,520 | 46,807 |
| Oct | 29,211 | 31,769 | 42,001 |

proximate presence of immediate family. Their limited exposure to news media and social media did not allow them timely access to evacuation alerts. When they were eventually identified, they needed tailored care, assistive devices, medicines, specialized diets, and additional space in relief camps. Similarly, due to the additional burden of rescuing, transporting, and containing them in relief camps, persons with disabilities (muscular dystrophy, autism, blindness, paralysis) were left at the mercy of relief workers. Many lost their assistive devices (canes, crutches, wheelchairs, hearing aids, urine bags, etc.) in flood. In addition to the physical ailments, the isolation, despair, and guilt felt by such persons took a tremendous mental health toll that is not easily measured by conventional health indicators (Thummarukudy & Peter, 2019).

The relief operations did not anticipate these challenges and were not equipped to handle the additional needs of these vulnerable populations in the relief camps. Although some civil society organizations working with the mentally ill and other vulnerable populations offered assistance, disaster management efforts need to be made sensitive to the different vulnerabilities and specific needs of the elderly and persons with disabilities.

Issues of mental health can be difficult to measure in India due to the stigma attached to mental illness (Chandran, 2018). Mental health has been an important aspect of Kerala's public health system, and Kerala is the only state in India to have the District Mental Health Program in all 14 districts. Since 2003, Kerala has had a mental health policy in place, and the policy was revised in 2013, but there is no written action plan, which limits the capacity for implementation (Shibukumar, 2017). Only 1.16 percent of the State Health Department's budget was allocated to mental health in 2017. However, there are several NGOs offering mental health services and the state is well-positioned to become an exemplar in mental health delivery (India State-Level Disease Burden Initiative Mental Disorders Collaborators, 2020; Kottai & Ranganathan, 2020).

## Conclusions and Recommendations

A case study of the health impacts of the Kerala floods suggests that, in the developing world, impressive achievements in climate-induced disaster management and emergency health care can be achieved through a well-funded public healthcare system and coordinated public action among governmental and non-governmental actors. The capacities of Kerala's public institutions and the resilience of Kerala civil society were tested by the floods. Rising to the challenge, citizens, nongovernment agencies, and the government joined hands at various levels to mount what was a unique community-oriented approach to disaster mitigation and emergency health care. Disaster management with an emphasis on building strategic partnerships with NGOs and other civil society organizations, which function at once as collaborators and critics of the state, ensures relief efforts that are transparent, responsive, effective, and efficient. It ensures buy-in from the population, rapid dissemination of accurate and reliable health information, compliance, and swift reach and execution, even in the proverbial last mile. Harnessing the synergy of people's participation and volunteerism for development has been a historic feature of Kerala. The 2018 flood demonstrated that the same state–society pact could be leveraged for mitigating the health impact of natural disasters.

In addition, the success of Kerala's flood relief in general and health interventions in particular hinged on Kerala's ability to offer a comprehensive vision for rescue and recovery, and to implement it through the coordinated use of its competent public service. This too is an important lesson for other developing-world societies, as vapid political leadership and incompetent and uncoordinated bureaucracy can stymie effective relief. Kerala was able to establish a clear chain of command and ensure complementary intersectoral coordination among several government departments and ministries, including finance, revenue, home, health, agriculture, animal husbandry, fisheries, forestry, land, livelihoods, roads and bridges, transportation, urban services and infrastructure, water supply and sanitation, water resources management, environment, social welfare, and local self-governments. The control rooms at the state level and at the district level were able to exercise authority over these diverse agencies to realize exceptionally quick and coordinated service delivery. The successful containment of the dangerous Nipah virus outbreak just months before the flood and the lessons learned therein in swiftly adopting necessary control and prevention protocols provided a current roadmap for rapid public health response.

Communication is a serious headache during any major disaster because traditional communications systems often break down under its weight. In Kerala, many people were stranded without access to land phones, cell phones, radio, television, or the internet due to continuous power outages. They could not access news or public service announcements and no one could contact them for days. An alternative mode of communication (in addition to the police networks) that will withstand the destruction caused by the disaster is necessary to quickly identify, reach and rescue marooned people. At the same time, the Kerala case also points to the innovative use of information technology and social media for the coordination of rescue efforts. Future research on Kerala's bourgeoning vernacular media and the media's role in raising awareness on the topics of climate change and public health is needed.

The Kerala case points to the need for better health data prior to and during the crisis. The data on the health impact of the Kerala floods is rather scarce. It is important to keep data on the health impact of floods, including longer-term mental health data, to enable state preparedness for future emergencies. This data has to incorporate the special needs of elderly persons, persons with mental health difficulties, and persons with disabilities. Disaster health relief efforts need to be broadened to include mental health and the services of trained mental health personnel. A natural disaster would only exacerbate pre-existing mental health conditions. The Geographical Information System (GIS) database and geotagging can be used effectively during disasters to identify these health needs and send relief. They can also help first responders to use their time more efficiently to reach people in need and effectively communicate with them.

The 2018 floods clearly highlighted some key gaps in Kerala's disaster prevention system. A pro-active, comprehensive, and coordinated approach to preventing climate change vulnerability was missing. Poor availability of reliable data for disaster risk planning and management, unsustainable management of water resources (rivers, flood plains, watersheds, dams), extensive exploitation of natural resources (deforestation, sand mining from rivers, and stone quarrying from hilly areas, construction on flood plains), lack of proper sensitivity about the immediacy and increasing likelihood of climate-induced disasters, and, above all, the lack of an integrated flood risk management plan that integrates disaster management with development planning are some of the policy and implementation gaps we observed. The development of better early warning systems and flood management systems is essential. Better flood control is necessary for vulnerable communities at high risk of recurrent flooding.

Future risk reduction and adaptation require careful and coordinated action on all of the above fronts, some of which the Kerala government has already begun. After the immediate rescue and relief efforts, the government developed a comprehensive roadmap to recovery and reconstruction through a participatory and inclusive process. The government established the "Rebuild Kerala Initiative" (RKI) in consultation with domestic and international partners, including the World Bank and the United Nations, to develop, coordinate, and facilitate recovery. The plan to rebuild not only addressed the fundamental drivers of floods and other natural disasters but also saw rebuilding as an opportunity to better prepare for future disasters. RKI's mandate is to rebuild by "adopting higher standards of infrastructure for recovery and reconstruction, and to build ecological and technical safeguards so that the restructured assets could better withstand floods in the future" (Rebuild Kerala, 2018). Recognizing that floods are likely to occur with greater regularity, the government of Kerala is actively engaged in adaptation and mitigation activities, including mainstreaming disaster management, establishing a stronger techno-legal framework, and collecting remote sensing data to model and predict floods.

Returning to the key lessons of this case study, a functioning democracy, competent bureaucracy, decentralized and participatory institutional design, a vibrant civil society, and a literate citizenry have all been vital ingredients in Kerala's story. Early social mobilization and iterated demands from below for expansion of social rights created the right conditions for the public provision of a range of social goods, including education and health care. This cumulative extension of social policy enhanced the basic capabilities of Kerala's citizens to participate in politics, in associational activity, and in collaborative local-level institutions. In effect, Kerala's experience points to the dynamic and symbiotic interaction between state capacity and social mobilization, between governmental performance and popular participation, resulting in a virtuous cycle of effective public intervention. That state capacity and social mobilization can produce mutually reinforcing effects in disaster management and public health is a distinctive lesson of the Kerala experience.

## Notes

Conflicts of interest: None declared.

**Corresponding author**: Anil Varughese, anil.varughese@carleton.ca

**Anil Varughese, PhD**, is an assistant professor in the School of Public Policy and Administration, Carleton University, Ottawa, Canada.

**Chithra Purushothaman, PhD**, is a post-doctoral fellow in the School of Public Policy and Administration, Carleton University, Ottawa, Canada.

## References

Abhilash, S. 2019. "Kerala Floods: The Climate Factor." *Frontline* (September 13). https://frontline.thehindu.com/the-nation/article29277194.ece

Akhtar, Rais. 2020. Introduction: Extreme Weather Events and Human Health: A Global Perspective. *Extreme Weather Events and Human Health: International Case Studies* (pp. 3–11). New Delhi: Springer. https://doi.org/10.1007/978-3-030-23773-8

Akpinar-Elci, Muge, Rose Shanomae, and Kekeh Michele. 2018. "Well-being and Mental Health Impact of Household Flooding in Guyana, The Caribbean." *Marine Technology Society Journal* 52 (2): 18–22.

Alderman, Katarzyna, Lyle R. Turner, and Shilu Tong. 2012. "Floods and Human Health: A Systematic Review." *Environment International* 15 (47): 37–47.

Balica, S. F., N. G. Wright, and F. van der Meulen. 2012. "A Flood Vulnerability Index for Coastal Cities and its Use in Assessing Climate Change Impacts." *Natural Hazards* 64: 73–105.

Basheer, K. P. M. 2019. "Redirecting Money From the Gulf." *The Hindu* (October 14). https://www.thehindu.com/opinion/op-ed/redirecting-money-from-the-gulf/article29674257.ece

Bei, Bei, Christina Bryant, Kim-Michelle Gilson, Juliana Koh, Penelope Gibson, Angela Komiti, Henry Jackson, and Fiona Judd. 2013. "A Prospective Study of the Impact of Floods on the Mental and Physical Health of Older Adults." *Aging and Mental Health* 17 (8): 992–1002.

CBHI. 2018. *National Health Profile 2018*, New Delhi: Government of India, Central Bureau of Health Intelligence. http://cbhidghs.nic.in/WriteReadData/l892s/Before%20Chapter1.pdf

CBHI. 2019. *National Health Profile 2019*, New Delhi: Government of India, Central Bureau of Health Intelligence. http://www.cbhidghs.nic.in/WriteReadData/l892s/8603321691572511495.pdf

Colwell, Rita R. 2006. "Global Climate and Health: Predicting Infectious Disease Outbreaks." *Innovations* 1 (3): 19–23.

Devasia, T. K. 2018. "Kerala Floods Leave Several Hospitals in Disarray: Many Surgeries Cancelled, Doctors Fear Health Crisis May Worsen." *Firstpost* (August 17). https://www.firstpost.com/india/

kerala-floods-leave-several-hospitals-in-disarray-many-surgeries-cancelled-doctors-fear-health-crisis-may-worsen-4986101.html

Dhiman, Ravinder, Renjith VishnuRadhan, T. I. Eldho, and Arun Inamdar. 2019. "Flood Risk and Adaptation in Indian Coastal Cities: Recent Scenarios." *Applied Water Science* 9 (5): 1–16. https://doi.org/10.1007/s13201-018-0881-9

DHS. 2019. *Data on Communicable Diseases 2018 Kerala State*. Directorate of Health Services. http://dhs.kerala.gov.in/wp-content/uploads/2020/03/cddata_07052019.pdf

DHS. 2020. *Data on Communicable Diseases*. Directorate of Health Services. http://dhs.kerala.gov.in/data-on-communicable-diseases/

Dreze, Jean, and Amartya Sen. 1989. *Hunger and Public Action*. Oxford: Oxford University Press. http://dx.doi.org/10.1093/0198283652.001.0001

Elamon, Joy, Richard W. Franke, and B. Ekbal. 2004. "Decentralization of Health Services: The Kerala People's Campaign." *International Journal of Health Services* 34 (4): 681–708.

EPA. 2018. *Potential Well Water Contaminants and Their Impacts*, United States Environmental Protection Agency. http://www.epa.gov/privatewells/potential-well-water-contaminants-and-their-impacts

Faleiro, Sonia. 2020. "What the World Can Learn From Kerala About How to Fight Covid-19." *Technology Review*. April 13. https://www.technologyreview.com/2020/04/13/999313/kerala-fight-covid-19-india-coronavirus/

Gadgil Commission. 2011. *Report of the Western Ghats Ecology Expert Panel. Submitted to The Ministry of Environment and Forests*. Government of India. https://ruralindiaonline.org/en/library/resource/report-of-the-western-ghats-ecology-expert-panel/

Gage, Kenneth L., Thomas R. Burkot, Rebecca J. Eisen, and Edward B. Hayes. 2008. "Climate and Vectorborne Diseases." *American Journal Preventive Medicine* 35 (5): 436–50.

India State-Level Disease Burden Initiative Mental Disorders Collaborators. 2020. "The Burden of Mental Disorders Across the States of India: The Global Burden of Disease Study 1990-2017." *Lancet Psychiatry* 7: 148–51.

*Indian Express*. 2018. "483 Dead in Kerala Floods and Landslides." Losses More Than Annual Plan Outlay: Pinarayi Vijayan." *Indian Express* (August 30). https://indianexpress.com/article/india/483-dead-in-kerala-floods-and-landslides-losses-more-than-annual-plan-outlay-pinarayi-vijayan-5332306/

IPCC. 2014. *Fifth Assessment Report*. Intergovernmental Panel on Climate Change.

IPCC. 2018. *Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, In the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_Low_Res.pdf

Isaac, T. M. Thomas, and Rajeev Sadanandan. 2020. "COVID-19, Public Health System and Local Governance in Kerala." *Economic & Political Weekly LV* 21: 35–40.

Jacob, Suraj. 2014. "The Kerala Regime and Regional Disparities in Health Infrastructure Versus Outcomes." *India Review* 13 (1): 58–77.

Jaya Divakaran, Soumya, Jamiema Sara Philip, Padma Chereddy, Sai Ravi Chandra Nori, Akshay Jaya Ganesh, Jiffy John, and Shijulal Nelson-Sathi. 2019. "Insights Into the Bacterial Profiles and Resistome Structures Following the Severe 2018 Flood in Kerala, South India." *Microorganisms* 7 (10): 474.

Kannan, K. P., and K. S. Hari. 2020. "Revisiting Kerala's Gulf Connection: Half a Century of Emigration, Remittances and their Macroeconomic Impact, 1972–2020." *The Indian Journal of Labour Economics* 63: 941–67. https://doi.org/10.1007/s41027-020-00280-z

Kannan, Srinivasan, and Margret Frenz. 2019. "Seeking Health Under Palm Trees: Ayurveda in Kerala." *Global Public Health* 14.3 (2019): 351–61.

Kasturirangan, Krishnaswamy, C. R. Babu, J. M. Mauskar, Kanchan Chopra, J. Kishwan, D. Shankar, S. Narain, P. S. Roy, A. Tyagi, and I. Chandrasekharan. 2013. "Report of the High Level Working Group on Western Ghats." Submitted to the Ministry of Environment and Forests, Government of India.

Kottai, Sudarshan R., and Shubha Ranganathan. 2020. "Task-Shifting in Community Mental Health in Kerala: Tensions and Ruptures." *Medical Anthropology* 39 (6): 538–52.

KSDMA. 2011. *Kerala State Disaster Management Plan Profile*. Kerala State Disaster Management Authority, Government of Kerala. http://www.kerenvis.nic.in/WriteReadData/UserFiles/file/49412317-Kerala-Disaster-Management-Plan-Profile-India.pdf

KSDMA. 2016a. *Kerala State Disaster Management Plan 2016*. Kerala State Disaster Management Authority, Government of Kerala. http://sdma.kerala.gov.in/publications/DMP/Kerala%20State%20Disaster%20Management%20Plan%202016.pdf

KSDMA. 2016b. *Handbook: Disability and Disaster Risk Reduction*. Kerala State Disaster Management Authority, Government of Kerala. https://sdma.kerala.gov.in/wp-content/uploads/2018/11/Handbook-Different-Ability-2016.pdf

KSDMA. 2018. *Kerala Floods—2018*. Kerala State Disaster Management Authority, Government of Kerala. https://sdma.kerala.gov.in/wp-content/uploads/2019/08/Memorandum2-Floods-2018.pdf

Krishnan, R., J. Sanjay, Chellappan Gnanaseelan, Milind Mujumdar, Ashwini Kulkarni, and Supriyo Chakraborty. 2020. *Assessment of Climate Change Over the Indian Region: A Report of the Ministry of Earth Sciences (MoES)*, Government of India. https://10.1007/978-981-15-4327-2

Kumar, Pramod G. 2019. "Nipah Virus: Kerala Government Acted Quickly, But Recurrence a Sign That State's Once Immaculate Healthcare System is Failing." *Firstpost* (June 10). https://www.firstpost.com/india/nipah-virus-kerala-govt-acted-quickly-but-recurrence-a-sign-that-states-once-immaculate-healthcare-system-is-failing-6777941.html

Kutty, V. Raman. 2000. "Historical Analysis of the Development of Health Care Facilities in Kerala State, India." *Health Policy and Planning* 15: 103–09.

Mendell, Mark J., Anna G. Mirer, Kerry Cheung, My Tong, and Jeroen Douwes. 2011. "Respiratory and Allergic Health Effects of Dampness, Mold, and Dampness-Related Agents: A Review of the Epidemiologic Evidence." *Environ Health Prospect* 119 (6): 748–56.

Nabae, Koji. 2003. "The Healthcare System in Kerala: Its Past Accomplishments and New Challenges." *Journal of National Institute of Public Health* 52 (2): 140–145.

Nageswara Rao, K., Subraelu, P., Venkateswara Rao, T., Hema Malini, B., Ramakrishnan, R., Bhattacharya, S., & Ajai, (2008). Sea-level rise and coastal vulnerability: an assessment of Andhra Pradesh coast, India through remote sensing and GIS. *J Coast Conserv*, 12, 195–207.

NITI Aayog. 2018. *Composite Water Management Index: A Tool for Water Management*. NITI Ayog (National Institution for Transforming India) Report. June 2018. http://www.social.niti.gov.in/uploads/sample/water_index_report.pdf

———. 2019. *Healthy States, Progressive India: Report on the Ranks of States and Union Territories*, New Delhi: NITI Aayog (National Institution for Transforming India), Government of India. https://niti.gov.in/writereaddata/files/Healthy-States-Progressive-India-Report.pdf

Paliath, Shreehari. 2018. "How Kerala Staved Off A Health Crisis That The August Floods Could Have Unleashed." *IndiaSpend* (November 18). https://www.indiaspend.com/how-kerala-staved-off-a-health-crisis-that-the-august-floods-could-have-unleashed/

Pandey, Kiran. 2018. "Warnings from the Past: Sea Levels Will Rise, 78 Indian Cities to See Floods." *Down to Earth* (June 28). https://www.downtoearth.org.in/news/india/warnings-from-the-past-sea-levels-will-rise-78-indian-cities-to-see-floods-60981

Patz, Jonathan A., Diarmid Campbell-Lendrum, Tracey Holloway, and Jonathan A. Foley. 2005. "Impact of Regional Climate Change on Human Health." *Nature* 438: 310–317.

PHCPI. 2020. Kerala, India: Decentralized Governance and Community Engagement Strengthen Primary Care. *Promising Practices*, The Primary Health Care Performance Initiative. https://improvingphc.org/promising-practices/kerala

Rajan, Irudaya S. 2004. "From Kerala to the Gulf: Impacts of Labor Migration." *Asian and Pacific Migration Journal* 13 (4): 497–509.

Rajiv, G. 2018. "Flood Damages in Kerala Pegged at Rs 40,000 Crore." *The Times of India* (September 13). https://timesofindia.indiatimes.com/city/thiruvananthapuram/kerala-lost-rs-40000-cr-due-to-floods-report-will-be-submitted-to-centre/articleshow/65783705.cms

Ramakumar, R. 2006. "Public Action, Agrarian Change and the Standard of Living of Agricultural Workers: A Study of a Village in Kerala." *Journal of Agrarian Change* 6 (3): 306–45.

Rebuild Kerala. 2018. "Rebuild Kerala Development Programme: A Resilient Recovery Policy Framework and Action Plan for Shaping Kerala's Resilient, Risk-Informed Development and Recovery from 2018 Floods." Government of Kerala. https://kerala.gov.in/documents/10180/5f7872f9-48ab-40c8-bf3f-283d8dceacfe

Rose, Shanomae, and Muge Akpinar-Elci. 2015. "An Evaluation of the Prevalence of Respiratory and General Symptoms Among Occupants of Households Affected by Flooding in Guyana: The Case of Cove & John." Proceedings of the University of Guyana Faculty of Natural Sciences First International Conference on Sustainable Development, August 12–14, 2013. https://jare.org.gy/wp-content/uploads/2015/12/Rose-S-An-evaluation-of-the-prevalence-of-respiratory-FNS.pdf

Saulnier, Dell D., Kim Broline Ribacke, and Johan von Schreeb. 2017. "No Calm After the Storm: A Systematic Review of Human Health Following Flood and Storm Disasters." *Prehospital and Disaster Medicine* 32 (5): 568–79.

Sekulova, Filka, and J. C. J. M. Van den Bergh. 2016. "Floods and Happiness: Empirical Evidence From Bulgaria." *Ecological Economics* 126.C: 51–7.

Semenza, Jan C., and Jonathan E. Suk. 2018. "Vector-Borne Diseases and Climate Change: A European Perspective." *FEMS Microbiology Letters* 365 (2): fnx244.

Sen, Sandip. 2018. "Improved Disaster Management Saves Kerala, Despite Lack of Preparedness." Observer Research Foundation. https://www.orfonline.org/expert-speak/43901-improved-disaster-management-saves-kerala-despite-lack-of-preparedness/

Shaji, K. A. 2019. "Is Climate Change Making Floods an Annual Affair in Kerala?" *The Wire* (August 14). https://thewire.in/environment/floods-in-kerala-experts-point-to-climate-change

Shibukumar, Thavody J. 2017. *National Mental Health Survey of India, 2015-16: Kerala State Report*. Kozhikode, Kerala: Institute of Mental Health and Neuro Sciences. http://indianmhs.nimhans.ac.in/Docs/statereports/Kerala-NMHS-Report.pdf

St. Louis, Michael E., and Jeremy J. Hess. 2008. "Climate Change: Impacts on and Implications for Global Health." *American Journal of Preventive Medicine* 35 (5): 527–38.

Sunny, Justin, Jajati K. Parida, and Mohammed Azurudeen. 2020. "Remittances, Investment and New Emigration Trends in Kerala." *Review of Development and Change* 25 (1): 5–29.

Thakkar, Himanshu. 2018. "Role of Dam's in Kerala's Flood Disaster." *Economic and Political Weekly* 53: 38.

Thiagarajan, Kamala. 2018. "How Social Media Came To The Rescue After Kerala's Floods." *NPR* (August 22). https://www.npr.org/sections/goatsandsoda/2018/08/22/640879582/how-social-media-came-to-the-rescue-after-keralas-flood

Thummarukudy, Muralee, and Benoy Peter. 2019. *Leaving No One Behind: Lessons from the Kerala Disasters*, Perumbavoor, Kerala: Center for Migration and Inclusive Development.

Venkatesh, Shreeshan, and Rejimon Kuttappan. 2018. "*This is Why Kerala Floods Were the Worst in a Century*." *Down to Earth* (September 12). https://www.downtoearth.org.in/author/shreeshan-venkatesh-2424

Wallemacq, Pascaline, and Maria Moitinho de Almeida. 2018. "Flash Floods: Sharing of Field Experience-Kerala." *Cred Crunch* 53 (December): 1–2.

WHO. 2009. *Protecting Health from Climate Change, Connecting Science, Policy and People*. Geneva: World Health Organization.

WHO. 2018. *Outbreak of Nipah Virus Encephalitis in the Kerala State of India*, World Health Organization. no date. https://www.who.int/southeastasia/outbreaks-and-emergencies/health-emergency-information-risk-assessment/surveillance-and-risk-assessment/nipah-virus-outbreak-in-kerala

Zachariah, K. C., E. T. Mathew, and S. Irudaya Rajan. 2001. "Impact of Migration on Kerala's Economy and Society." *International Migration* 39 (1): 63–87.

World Medical and Health Policy



# At Ground Zero—Emergency Units in Low- and Middle-Income Countries Building Resilience for Climate Change and Human Health

**Caitlin Rublee, Corey Bills, Cecilia Sorensen, Jay Lemery, and Emilie Calvello Hynes**

*Climate change is harming human health with disproportionate impacts on vulnerable populations. As extreme weather events are projected to increase, acute care services—the primary access point for patients during a disaster—will be increasingly stressed. The authors seek to assess current efforts to build resilience against climate-related events in emergency units in low- and middle-income countries (LMICs). A systematic review was done using Ovid Medline, Embase, Cochrane, and Global Health (CABI), combining LMICs, climate change, emergency care, and resilience terms. LMIC emergency units serve as a ground zero during times of disaster, yet countries have a myriad of emergency care systems, with varied stages of development and a limited capacity for surges in demand. There was little evidence and a paucity of standardization methods for building healthcare facility/system resilience. This study provides policy recommendations for strengthening LMIC emergency care systems to protect lives and advance health equity.*

**KEY WORDS:** climate change, resilience, emergency care systems, education, preparedness

## Introduction

Climate change directly and indirectly harms human health and is predicted to worsen as climate models predict more intense and frequent disasters in coming years (IPCC, 2014). The list of consequential environmental impacts includes rising temperatures, wildfires, floods, tropical cyclones, dust storms, and droughts (IPCC, 2014; Watts et al., 2019). Infectious disease outbreaks (Sukhralia et al., 2019; Waits, Emelyanova, Oksanen, Abass, & Rautio, 2018; Wu, Lu, Zhou, Chen, & Xu, 2016), acute exacerbations of chronic diseases (Friel et al., 2011; Pruss-Ustiun et al., 2019), mental health affects (Obradovich, Migliorini, Paulus, & Rahwan, 2018; Padhy, Sarkar, Panigrahi, & Paul, 2015) and trauma caused by violence (Dennis et al., 2019; Hsiang, Burke, & Miguel, 2013; Levy, Sidel, & Patz, 2017) have all been associated with a rapidly warming planet. These impacts disproportionately affect the most socially and medically vulnerable (IPCC, 2014) and present a global challenge in the delivery of time-sensitive acute healthcare services.



doi: 10.1002/wmh3.417

*Disproportionate Burden of Climate-Related Health Effects on LMICs*

Low- and middle-income countries (LMICs) experience a larger burden of adverse health effects from increasing climate variability despite their much smaller contribution to global greenhouse gas emissions (Barbier & Hochard, 2018; Diffenbaugh & Burke, 2019; IPCC, 2014; Levy & Patz, 2015). This has always been a historic reality, now increasingly exacerbated by climate change. From 1950 to 2000, four climate-sensitive health conditions—malaria, malnutrition, diarrheal illness, and inland flood-related fatalities—were much higher in LMICs, primarily African countries, compared with high-income countries (HICs) (Patz, Holly, Foley, Rogers, & Smith, 2007). Climate-driven storms and heavy precipitation also destroy crops and contribute to food insecurity; malnutrition directly influences 45 percent of deaths for children under 5 and causes stunted growth in a further 149 million children (World Health Organization [WHO], 2018). Estimates indicate that 630 million more people will be impacted by increased coastal flooding by 2,100, with associated risks of vector-borne diseases and drowning (Kulp & Strauss, 2019). Climate-sensitive resource constraints for essential food, water, and healthcare needs are predicted to significantly strain both health systems and their communities in most predictive models (WHO, 2015b).

*Strengthening Resilience Within Health Systems*

In anticipation of the current and predicted burden on health systems, broader initiatives for building resilient health systems have been developed. The World Health Organization (WHO) has laid out an operational framework for climate-resilient health systems, which are founded on the six traditional building blocks: leadership and governance, health workforce, health information systems, service delivery, financing, and essential medical products and technologies. These building blocks are linked to ten additional components necessary for climate resilience (WHO, 2015a). For example, service delivery requires emergency preparedness and management, climate-informed health programs, and management of environmental determinants of health. Other high-level international frameworks highlight the impacts of climate change and disasters to assist countries with planning and adaptation. The United Nations Sendai Framework for Disaster Risk Reduction (United Nations, 2015) offers guidance to local, national, and regional sectors by emphasizing four priority areas: understand disaster risk, strengthen disaster risk governance to manage risk, invest in disaster risk reduction for resilience, and enhance preparedness for better response and recovery.

*Emergency Care Systems and Climate-Related Health Effects*

The effects of climate change on the emergency care system are well described in HICs (Aitken et al., 2015; Bucher et al., 2018; Chowdhury et al., 2019; Davis & Novicoff, 2018; Doran et al., 2016; Ghazali et al., 2018; Hess, Saha, & Luber, 2014; Hutchinson et al., 2018; Lee et al., 2016; Liang & Messenger, 2018; Malik et al., 2018;

McQuade et al., 2018). This data suggests that climate change is likely to increase the incidence of emergency conditions, disproportionately affect patients who rely on acute care in emergency units, present marked increases in vector-borne and environmentally driven diseases, and stress current emergency systems with increased frequency and severity of disasters.

For LMICs, little is known about the effects of climate on emergency care systems. We do know that climate-sensitive illnesses are projected to increase in LMICs (IPCC, 2014; Wu et al., 2016). Flooding after heavy rainfall can breach water systems and sanitation, leading to diarrheal disease outbreaks (cholera); likewise, standing water promotes *Anopheles* mosquito breeding and subsequent malaria transmission. Another effect is an increase in acute-on-chronic respiratory disease exacerbations (asthma and chronic obstructive pulmonary disease) from worsening ambient air pollution. For many people suffering from these climate-related health effects, emergency care is the first—and sometimes only—point of contact with the health system. This reality is especially true for those with limited access to health care. Yet, in many LMICs, emergency care systems are newly established and markedly undeveloped (Kironji et al., 2018; Moresky et al., 2019). The fact that median mortality rates have been found up to 45 times higher in LMIC emergency units as compared with HIC emergency departments highlights this discrepancy (Kanzaria, Probst, & Hsia, 2016; Obermeyer et al., 2015; Tang, Stein, Hsia, Maselli, & Gonzales, 2010). The mortality rates seen in LMIC emergency units, even among a younger population, maybe due to poorly trained healthcare providers and lack of necessary equipment and other resources, such as electricity and running water (Obermeyer et al., 2015).

WHO has called for timely access to emergency care and strengthening of emergency care systems as a part of universal health coverage and improving public health (WHO, 2019a). Currently, large gaps exist in the ability to care for millions of patients who require everyday emergency care starting at the scene of illness/injury, during transport, and at healthcare facilities (WHO, 2019b). Critical resources such as life-saving medications, blood products, trained staff, transportation systems, clean water, and energy are not consistently available in many countries. Emergency care system development has halved mortality with some basic interventions (Siman-Tov, Radomislensky, Itg, & Peleg, 2013; Tallon, Fell, Karim, Ackroydstolarz, & Petrie, 2012). As acute climate-driven diseases increase, increasing numbers of patients will seek care in emergency units that are understaffed, overburdened, and with limited capacity. These endemic conditions manifest the need for prevention, preparedness, and treatment initiatives (Carlson, Reynolds, Wallis, & Calvello Hynes, 2019).

For health systems in LMICs, emergency units will be ground zero for climate-sensitive health emergencies such as mass casualty incidents from floods and tropical cyclones or increased demand of care due to heatwaves, exacerbated malnutrition, and vector-borne diseases. To date, there is very limited data on the effects that climate-related health effects currently have and may have in the future on emergency units in LMICs, and even less on what evidence-based actions should be taken to both prepare and respond. This manuscript reviews the current scope of the literature and provides a roadmap for addressing the current capacity gaps of LMIC emergency care systems at the frontline of health and climate change.

## Methods

### *Criteria for Considering Studies in This Review*

A scoping systematic review was completed using four bibliographic databases: Ovid Medline, Embase, Cochrane, and Global Health (CABI). A rigorous search strategy was designed in collaboration with a health sciences medical librarian with the goal of identifying climate change impacts on emergency care systems and units in LMIC, excluding individual health impacts from climate change. The search terms used encompass four broad categories: LMICs as defined by the World Bank, climate change exposures, emergency care settings, and resilience. Climate change exposures were taken from the National Institute of Environmental Health Sciences (NEHS) Climate Change and Human Health Literature Portal (https://tools.niehs.nih.gov/cchhl/) exposure data. See Table S1 for further details of search terms. A gray literature search was done in the NIEHS literature portal using "emergency" and "resilience" to supplement interventions to health systems in LMIC. These databases were searched from 2007 through 2018. We also searched reference lists of included articles for relevant works that may have been missed through the use of formal databases and search terms.

### *Search Methods for Identification of Studies*

Of the articles identified in our initial search strategy, duplicates were removed, and subsequent titles and abstracts were screened. Two independent teams (CR/CS and CB/ECH) conducted the title and abstract screening and full-text review. Emails to abstract authors were sent to confirm no full text available as of April 14, 2020. Any discrepancies were resolved by a third reviewer. EndNote bibliographic manager and Covidence online software assisted with the synthesis of review. The review protocol could not be registered with PROSPERO (University of York, United Kingdom National Institute for Health Research, United Kingdom of Great Britain and Northern Ireland) as a scoping review is an exclusion.

### *Data Collection and Analysis*

*Selection of Studies.* Both qualitative and quantitative studies were included. Only LMICs, as defined by the World Bank (The World Bank, 2020), and those that had a focus on healthcare facility resilience were included. The study focus was related to a climate exposure and emergency unit. Randomized controlled trials, observational studies, evaluations, reports, expert reviews, and qualitative studies were included. The following exclusion criteria were applied: (i) non-English language, (ii) full article not available, (iii) articles not related to climate change or climate exposure or climate hazards, (iv) articles without a healthcare facility or emergency unit setting editorials and conference abstracts without full text.

*Data Extraction and Management.* Information extracted from articles included author, year, country, study design, disaster/climate exposure, population, participants involved, problems identified, intervention and outcome of the intervention, and key conclusions for disaster preparedness.

Quantitative studies were assessed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) criteria, including very low, low, moderate, and high quality (Guyatt, Oxman, & Schunemann, 2011). Criteria proposed by the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement were adhered to in reporting (Moher et al. 2009). Qualitative studies were assessed using the Critical Appraisal Skills Programme (CASP) 10-item checklist (Critical Appraisal Skills Programme, 2020). A descriptive thematic analysis was performed due to the heterogeneous nature of the articles.

## Results

### *Overview*

Of the 107 articles initially identified in our search strategy, 22 duplicate articles were removed. Two additional articles were added by evaluation of references. In total, 87 studies were reviewed by title and abstract by two reviewers (CR/CS). Three articles were abstracts only. Emails to the abstract authors confirmed no full text available as of April 14, 2020 and excluded. The NIEHS Climate Change and Human Health Literature Portal search yielded 103 individual results, of which 35 were specifically to LMICs. After title and abstract screening, a total of 16 articles were reviewed for full-text screening (Figure 1).

Eight articles met full inclusion criteria after full-text review and were included for analysis (Table 1). The other eight studies were excluded due to a lack of focus on emergency care units or patients requiring emergency care. Of the included studies, four were mixed quantitative and qualitative methods, two qualitative and two quantitative studies. Seven countries were represented in the review, including two from Africa (Ethiopia and Tanzania), three island nations (Sri Lanka, Solomon Islands and Cuba), and two from Asia (Vietnam and China). Half of the studies were questionnaires varying in length from 25 to 161 items. Respondents represented healthcare systems as staff familiar with acute care services or disaster planning. Several studies included focus groups with other community partners to inform surveys.

The quality of included studies varied. All quantitative studies were rated as "Very Low" (Brown & Ategbo, 2017; Van Minh et al., 2014) or "Low" (Farley, Suraweera, Perera, Hess, & Ebi, 2017; Zhong et al., 2014; Koka et al., 2018) by GRADE criteria. There were no randomized controlled trials or prospective cohort studies. All questionnaires had informed consent. Not all studies acknowledged the

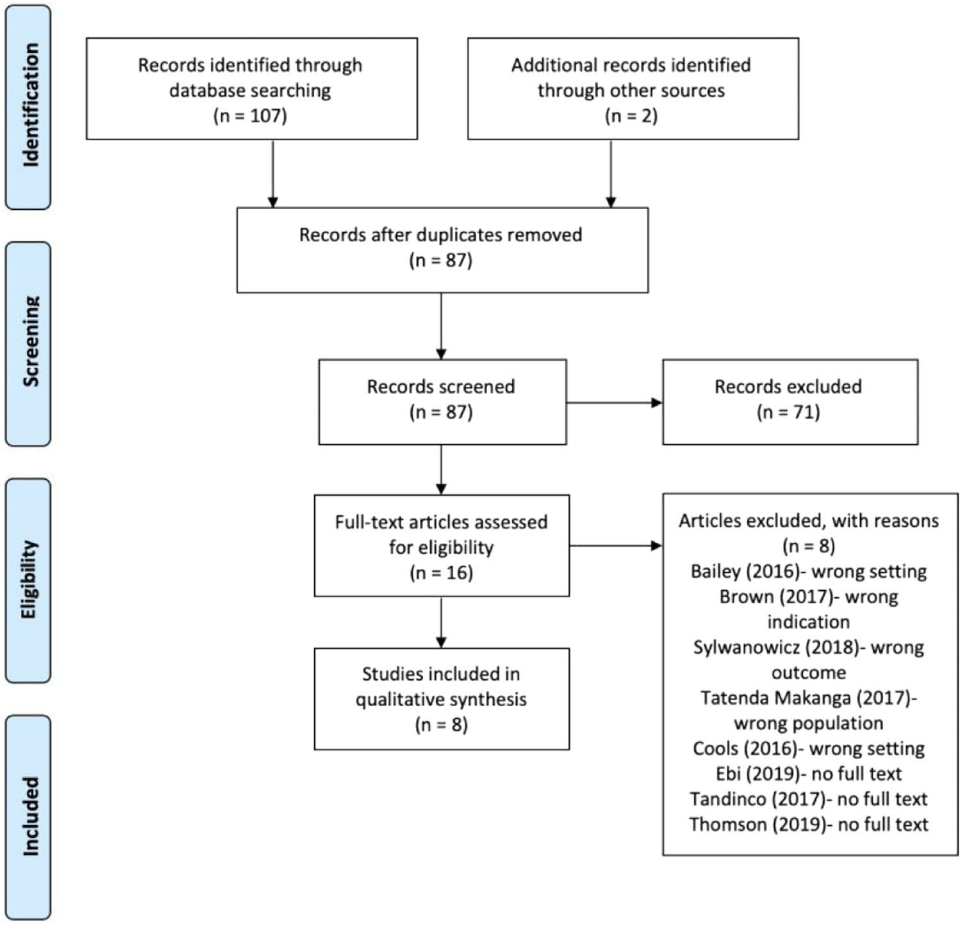



Figure 1 Prisma Flow Chart for Selected Studies.

ethical considerations of their work (Natuzzi et al., 2016; Zakrison, Valdes, & Shultz, 2020).

Summary analysis confirmed that the coastal, inland, and island nations under review in the studies were at-risk for harm from climate exposures. Their emergency units serve as the frontline for the effects of climate change with limited capacity for surges in demand. Resource allocation and deficiencies, health professional education, and infrastructure development emerged as three key themes for improvement. The following section describes the challenges and opportunities of these themes for leaders in government, organizations, and healthcare systems.

*Key Themes*

*Resource Allocation and Deficiencies.* Several articles highlighted both medical and human resource shortages that influence the delivery of quality emergency care. In Sri Lanka, 61 percent of respondents ($n = 31$ facilities) reported inadequate supplies

**Table 1.** Summary of Reviewed Articles

| Author (Year) | Setting (Country) | Study Design | Climate Exposure | Population | Health Setting | Intervention | Outcome | Lessons Learned | In NIEHS Literature Portal |
|---|---|---|---|---|---|---|---|---|---|
| Brown and Ategbo (2017) | Ethiopia | Case-control | Drought | Children and pregnant and lactating women | Staffed emergency nutrition coordination units during a prolonged drought crisis affecting hundreds of thousands of people in rural villages | Implementation of a year-round community-based nutrition intervention began in 2008 and was further supplemented with the introduction of ready-to-use therapeutic food (RUTF) when the food crisis worsened (2015–16). Severe acute malnutrition (SAM) cases were monitored monthly in areas of intervention as well as comparable rural communities without the nutrition intervention. | Communities receiving baseline nutritional support coupled with RUTF demonstrated: lower death rates (1% vs. 2%), higher cure rate (92% vs. 90%), and increased SAM treatment of eligible cases (95% vs. 76%). SAM cases increased by 40% in 2015 compared with average of previous years followed by a 28% increase in 2016. The prevalence of underweight children <2 years old was 25% in 2008 and 5% in 2016. The number of facilities treating SAM increased from 400 in 2008 to | Better coordination of regional and federal nutrition information systems improve reporting time and allocation of resources. A capacity mapping tool that analyzes physical accessibility to health bureaus can guide the allocation of resources. Real-time data is important for prompt planning and action. | No |

(*Continued*)

| Author (Year) | Setting (Country) | Study Design | Climate Exposure | Population | Health Setting | Intervention | Outcome | Lessons Learned | In NIEHS Literature Portal |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 15,000 in 2015. | | |
| Farley et al. (2017) | Sri Lanka | Questionnaire and intervews | Floods | Medical Officers in charge of public healthcare facilities and Medical Offices of Health | 31 public healthcare facilities and Medical Offices of Health in the Trincomalee District, a region subject to recurrent flooding events | 58 item questionnaire (adapted from the Hospital Safety Index) on flood history, communication before and during disasters, and disaster preparedness and 10 in-depth interviews assessed the experience of facility directors and the facility itself during flooding | In the last 5 years, 19% reported flooding to the facility and 61% reported flooding in their patient catchment areas. 58% reported access to backup generators and 93% reported running water to the facility at baseline. Only 13% of facilities had disaster plans. Of the six facilities that reported flooding, all had transportation disruptions, four had power outages, and two lost phone communication. Disaster education for staff was uncommon (13%). Longer tenure was associated with a higher level of confidence with | Workforce and resource shortages strain healthcare systems. Disaster plans are lacking as are plans to sustain basic healthcare operations during times of weather-related emergencies. Disaster education for staff is minimal, even in flood-prone areas. Emergency care and disaster education with a climate lens were recognized as important for health system disaster preparedness. | No |

(*Continued*)

| Author (Year) | Setting (Country) | Study Design | Climate Exposure | Population | Health Setting | Intervention | Outcome | Lessons Learned | In NIEHS Literature Portal |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | managing facilities during flooding. The majority (77%) reported inadequate staff, especially physicians, during weather emergencies. 61% reported concerns for inadequate supplies during flooding and other weather-related emergencies. Some facilities shared supplies under emergency settings. The majority of respondents felt somewhat prepared for floods. Regarding climate change, 90% believed that climate was affecting human health, 64% that climate change was occurring in Sri Lanka, 29% that | | |

(*Continued*)

| Author (Year) | Setting (Count-ry) | Study Design | Climate Exposure | Population | Health Setting | Intervention | Outcome | Lessons Learned | In NIEHS Literature Portal |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | flood and storms were stronger than previously, and 32% that storm events were occurring more frequently. | | |
| Koka et al. (2018) | Tan-zania | Questionnaire and interveiews | Disasters | Heads of hospital acute intake areas, head nurses, and medical officers | 25 regional hospitals in Tanzania (80% identified as rural) subject to frequent environmental disasters | 25 item questionnaire assessed disaster experience, type of personnel at hospitals, disaster protocols and planning, surge capacity, infrastructure, triage capacity, and communication | In the last 5 years, 92% of hospitals experienced an environmental disaster. 20% reported a hospital disaster plan. All hospitals had electricity and backup generators. There was a temporary morgue in 8% of hospitals and a fire alarm system in 8%. 20% had a stockpile of essential supplies and 68% had contigency plans. No hospital had a computed tomography scanner or a decontamination | There is a dearth of disaster preparedness among the majority of hospitals, which has resulted in shortages of human resources and skilled staff during times of disaster. Hospitals also lacked professionals trained in disaster and emergency medicine. Few had emergency protocols. All hospitals were deficient in surge capacity elements. | Yes |

(*Continued*)

| Author (Year) | Setting (Country) | Study Design | Climate Exposure | Population | Health Setting | Intervention | Outcome | Lessons Learned | In NIEHS Literature Portal |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | area. Gaps identified in disaster preparedness were in human resources (skilled workers in administrative roles), disaster planning, surge capacity, diagnostic imaging (one X-ray machine per facility), triage (presence or absence + / - trained personnel), fire alarm systems, decontamination area, and backup communication. | | |
| Natuzzi et al. (2016) | Solomon Islands | Vulnerability assessment | Floods | Hospitals and clinics | Healthcare facilities in the City of Honiara impacted by frequent flooding along the Mataniko River and coastline | A health system and population vulnerability assessment was completed using geographical information system (GIS) from the April 2014 floods | During the floods, the National Referral Hospital and three of nine main clinics were closed and evacuated due to flood damage. Through subsequent GIS mapping, 75% of Honiara's health | GIS mapping is a useful technique to assess health-care system vulnerability. Healthcare system resilience and community resilience are closely linked to urban planning | Yes |

(*Continued*)

| Author (Year) | Setting (Country) | Study Design | Climate Exposure | Population | Health Setting | Intervention | Outcome | Lessons Learned | In NIEHS Literature Portal |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | system was identified as vulnerable to future events, including four being "highly vulnerable." The hospital system is chronically overburdened, with an average bed occupancy rate of 200%. During the flooding, occupancy dropped 160%–170% then increased to 375% one month later due to a diarrheal disease outbreak. Rapidly urbanized areas appeared to be most vulnerable to flooding. | and land management, which need to be considered when constructing hospitals and managing rapid development. | |
| Shanahan et al. (2018) | Various | Qualitative review | Disasters | Emergency units and emergency care practitioners | Emergency care settings broadly | Not applicable | In addition to resources and knowledge, authors recommended increased political | Strengthening emergency care systems through high-impact and low-cost interventions will | No |

(*Continued*)

| Author (Year) | Setting (Country) | Study Design | Climate Exposure | Population | Health Setting | Intervention | Outcome | Lessons Learned | In NIEHS Literature Portal |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | leadership and practitioner advocacy to make emergency care a priority. Two focus areas were improving the value of emergency care and linking emergency care to global health priorities. Specific initiatives found to improve emergency care were in implementation of a triage system, basic emergency care training, and improved supervision of junior providers. Linking emergency care to global health priorities was found to support the Sustainable Development Goals (2015–30), World | help in the achievement of Sustainable Development Goals and Universal Health Coverage. | |

(*Continued*)

| Author (Year) | Setting (Country) | Study Design | Climate Exposure | Population | Health Setting | Intervention | Outcome | Lessons Learned | In NIEHS Literature Portal |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Health Organization workplan (2019–23), and Universal Health Coverage (2015–30). Developing emergency care systems was found to be key to disaster and public health preparedness. | | |
| Van Minh et al. (2014) | Vietnam | Questionnaire and interviews | Floods | Healthcare staff | 18 rural health facilities in the PhuVang district health-care system frequently affected by severe storms and flooding | A questionnaire and conducted focus groups targeting six WHO defined themes of resilient health-care systems | Damage to buildings, power outages, limited funding, and lack of staff were the greatest challanges reported during storms and subsequent flooding. All facilities lacked robust early warning systems and facility-level emergency plans. For service delivery, all facilities had essential | Contingency funds are needed for healthcare facility resilience emergency response to climate-related disasters, including flooding. Resilience can be improved with computerized health information systems to accelerate information and data processing, | Yes |

(*Continued*)

| Author (Year) | Setting (Count-ry) | Study Design | Climate Exposure | Population | Health Setting | Intervention | Outcome | Lessons Learned | In NIEHS Literature Portal |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | medications and 78% reported having sufficient supplies even during storms. Concerns for supply shortage were expressed by 22%. 36% reported emergency treatment disruptions (surgical operations, referrals). 63% rated the emergency referral system as poor and 73% reported inadequate quality emergency surgical services. Paper documentation with poor storage and misplaced referrals was another patient care concern. For education, a disaster simulation exercise found that | implementation of comprehensive training and education programs for healthcare staff and emergency treatment protocols for rural communities. | |

(*Continued*)

| Author (Year) | Setting (Country) | Study Design | Climate Exposure | Population | Health Setting | Intervention | Outcome | Lessons Learned | In NIEHS Literature Portal |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 80% of the medical staff treated common acute illnesses at least fair. All professional health-care staff received at least one session in the last 3 years on climate-related disasters, yet 86% said trainings were inadequate and 79% said they needed disaster planning or other specialized emergency plan skills. Public health educational interventions were found to increase knowledge about health risks arising due to floods. Village health workers were found to be important for initiating basic first-aid. All | | |

(*Continued*)

| Author (Year) | Setting (Country) | Study Design | Climate Exposure | Population | Health Setting | Intervention | Outcome | Lessons Learned | In NIEHS Literature Portal |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | respondents stated better intersectoral coordination was needed. | | |
| Zakrison et al. (2020) | Cuba | Qualitative case study | Hurricane | All island healthcare facilities | 71 hospitals on an island nation frequently struck by tropical storms and hurricanes | A healthcare infrastructure damage assessment was performed following Hurricane Irma in 2017 | Infrastructure weaknesses included structural damages and backup generator failures in three major hospitals. Although not explicitly stated to affect the hospital food or water services, more than 95,000 hectares of agricultural lands were flooded, and community disruptions in clean water lasted for months after the storm. Recognized keys to success were preemptively opening hospital beds to prepare for surges in demand, thousands of physicians who | Five features of disaster preparedness were highlighted as keys to Cuba's successes during Hurricane Irma: (i) learn and incorporate lessons from past disasters; (ii) integrate health-care and public health professions at the forefront of disaster response; (iii) actively engage the public in disaster; preparedness (iv) incorporate technology into disaster risk reduction; (v) infuse science into disaster risk planning. | Not applicable |

(*Continued*)

| Author (Year) | Setting (Country) | Study Design | Climate Exposure | Population | Health Setting | Intervention | Outcome | Lessons Learned | In NIEHS Literature Portal |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | were prepositioned in emergency evacuation centers or remote clinics, and practitioners in transport vehicles ready to deliver timely care. Other strengths were a decentralized network of generator substations and available personnel to fix electrical grids. Cuba's approach to education and communication involves all citizens with a national disaster preparedness curricula starting in primary schools, coordinated through the Risk Reduction Management Center. Climate change and | | |

(*Continued*)

| Author (Year) | Setting (Country) | Study Design | Climate Exposure | Population | Health Setting | Intervention | Outcome | Lessons Learned | In NIEHS Literature Portal |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | science-based initiatives were identified as keys to minimizing the impacts of future storms on Small Island Developing States. | | |
| Zhong et al. (2014) | China | Questionnaire | Disasters | Department directors | 41 tertiary A ($n = 27$) and B ($n = 14$) hospitals (regional facilities providing specialized medical care with an A subgroup having more services than B) in the disaster-prone Shandong Province | 161 item questionnaire on hospital disaster resilience organized by eight key domains (leadership, plan, stockpile, safety, critical care, staff, training, recovery) | Grade A hospitals achieved a higher mean resilience score than Grade B hospitals. All hospitals had a general plan for emergencies but 68% specifically for fires and 36% for floods. 22% had Memorandum of Understandings with nearby facilities to share supplies during disasters. 61% had backup energy and dedicated facilities for backup, including power, water, oxygen, and communication. B | Comprehensive surveys improve disaster resilience and hospital safety by identifying weaknesses and deficits in planning. | No |

(*Continued*)

| Author (Year) | Setting (Country) | Study Design | Climate Exposure | Population | Health Setting | Intervention | Outcome | Lessons Learned | In NIEHS Literature Portal |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | hospitals had no portable medical equipment available. Two facilities had helicopters for transport with landing zones expressed as an infrastructure concern. Only 36% of hospitals could increase their bed availability for surges and 12% had the capacity to staff those beds. | | |

if a weather emergency struck (Farley et al., 2017). Koka and colleagues detailed triage, communication, and infrastructure factors that were necessary but deficient, to support hospital operations (Koka et al., 2018). Their survey ($n = 25$ facilities) demonstrated that 8 percent had fire alarm systems, 20 percent had a stockpile of essential supplies, no facility had computed tomography (CT) imaging, few had portable X-ray imaging, and 8 percent had a temporary morgue. These examples of shortages highlight major gaps that limit emergency care operations and ultimately impact health outcomes, specifically, reduced capacity to communicate risks to facilities, shortage of supplies to provide needed care despite more patients, and lack of space to store deceased patients.

Examples of critical supply shortages during climate-related events were expressed by the authors. In Vietnam, 22 percent of responding healthcare facilities reported supply shortages of medications during recent floods (Van Minh et al., 2014). In Cuba, Hurricane Irma caused electrical disruptions for 11.5 million people (Zakrison et al., 2020). Seventy-one hospitals were affected, and three major facilities lost backup generator power and experienced a critical lack of electricity to run essential infrastructure such as telecommunications. Lack of backup communication via radios was identified in Tanzania (Koka et al., 2018). In Ethiopia, a drought contributed to shortages in emergency nutrition for children and infants, leading to malnutrition (Brown & Ategbo, 2017).

Proposed solutions varied in strength and uniformity. One study argued for establishing a Memorandum of Understandings (MOUs) with surrounding hospitals to share supplies (Zhong et al., 2014). Others that lacked specific, usable, and implementable disaster plans for healthcare systems stated a goal to enhance current disaster protocols through facility committees or via local collaboration (Koka et al., 2018; Van Minh et al., 2014; Zhong et al., 2014). Two studies highlighted the need for increased cooperation of healthcare facilities with village health workers and community public health for prevention (early warning systems, communication, addressing vulnerable populations) and response to disasters (nutrition, capacity building), especially in rural areas (Brown & Ategbo, 2017; Van Minh et al., 2014). Government officials, nongovernmental organization stakeholders, healthcare workers, public health, media outlets, committee members, and security personnel were identified as stakeholders collectively across all articles, although only Van Minh and colleagues explicitly included focus group input from a broad group of community stakeholders (Van Minh et al., 2014). Other solutions focused on reorganizing current resources to improve care at no added cost, such as initiating triage protocols (Shanahan, Risko, Razzak, & Bhutta, 2018). No included article mentioned crisis standards of care in preparation for catastrophic disasters.

*Health Professional Education.* Two educational gaps revealed in the review were lack of training in emergency care and lack of training for climate-related disasters. Emergency care education was mainly self-driven with a lack of continuing education opportunities (Farley et al., 2017). In China, clinical staff had a training curriculum in 85 percent of facilities but only 63 percent included basic trauma management, 56 percent on patient transfers, and 12 percent for triage (Zhong et al., 2014). Triage training was also lacking in Tanzania, where only 16 percent of hospitals had guidelines and 32 percent had training in triage (Koka et al., 2018). There were no emergency physicians who worked at any of the regional hospitals in Tanzania (Koka et al., 2018). During times of increased healthcare strain, trained staff shortages were projected to be greater.

Clinical staff had minimal training in managing climate-related disasters. When clinical trainings were offered in China, only 12 percent of trainings incorporated disaster management (Zhong et al., 2014). In Vietnam, an educational intervention on climate-related disasters was performed, yet 86 percent of respondents stated training was inadequate or not useful (Van Minh et al., 2014). One study sought to identify knowledge gaps in climate and health knowledge in local practitioners in Sri Lanka. Researchers interviewed local Medical Officers with an average of 3 years of work experience and found that 90 percent of respondents thought climate change could affect human health, 64 percent thought it was occurring locally, but only 29 percent thought flood and storm events were stronger than previously (Farley et al., 2017). In this same study, numerous respondents were not aware of the disaster preparedness plan or status at their own facility.

Training recommendations were focused on improving basic emergency care interventions such as on the acute treatment of injuries, rescue and evacuation, and emergency coordination (Farley et al., 2017; Shanahan et al., 2018). Another study specifically addressed increased training for triage nurses and attendants to prepare for high-demand times (Koka et al., 2018). For disaster education, three study authors urged increasing high-quality education of climate-related disasters, with two of the three authors specifying education of professional healthcare staff (Farley et al., 2017; Van Minh et al., 2014; Zakrison et al., 2020). The Ministry of Health in Sri Lanka even offered postgraduate diplomas in health sector disaster management (Farley et al., 2017). In Cuba, the authors recommended starting with population-level disaster education with a climate lens for all citizens and increasing capacity in the health sector by training and hiring health professionals specialized in disaster medicine to lead hospital-based committees (Zakrison et al., 2020). Using climate science was explicitly mentioned to inform early warning systems and disaster planning in Cuba (Zakrison et al., 2020).

*Infrastructure Development.* Building and physical infrastructures, such as energy and water systems, were reported to be unreliable or perceived to be inadequate to safely protect staff and patients while providing healthcare services (Natuzzi et al., 2016; Zhong et al., 2014). Specifically, one island nation reported that three of nine health clinics were recently damaged by floodwaters with subsequent geographical information system (GIS) results predicting vulnerability of 75 percent of health systems in future flood events (Natuzzi et al., 2016). Hospital safety concerns, including backup power and water in 61 percent of hospitals surveyed in China, prompted preemptive hospital evacuation as part of their disaster plan (Zhong et al., 2014). Zone infrastructure for air transport of patients was also an issue in the few facilities that had air transport available

(Zhong et al., 2014). For surge capacity in Vietnam, 66 percent had prepared for expanding electricity, oxygen, water, and space, although building damage and power outages already disrupted care (Van Minh et al., 2014). Paper records and poor storage of patient records and referrals were also a facility concern in one study (Van Minh et al., 2014). Rural locations and post-conflict areas were mentioned as barriers to infrastructure development in Sri Lanka, yet 93 percent of facilities reported having running water and 58 percent had a generator (Farley et al., 2017). In Tanzania, all hospitals surveyed had backup generators and electricity (Koka et al., 2018). While no specific frameworks were recommended, Farley and colleagues adapted their questionnaire from the Hospital Safety Index (Farley et al., 2017; WHO & PAHO, 2015).

Several authors proposed solutions to improve facility infrastructure. Solutions mentioned included enhanced communication (so hospitals could be part of a prompt chain of action), early warning systems, fire alarm systems, backup energy and communication, and computerized health information systems. In Cuba, the Risk Reduction Management Center improved their community disaster communication and coordination using scientific evidence and sophisticated mapping technologies (Zakrison et al., 2020). Geographical information system (GIS) technologies, land use regulation, and safe building codes were also proposed to assess vulnerable healthcare facilities along coastlines or waterways, even with external pressures of rapid urbanization (Natuzzi et al., 2016). Those regions that suffered a disaster previously stressed applying lessons learned to the next storm. In Cuba, deadly flooding from Hurricane Flora led to the creation of dams and flood abatement systems to minimize damage from floods and protect against droughts (Zakrison et al., 2020). Lastly, there was an emphasis on strengthening emergency care systems to align with international policy goals (Sustainable Development Goals and Universal Health Coverage).

## Discussion

In this paper, we provided an overview of the available literature regarding the impacts of climate-sensitive events on emergency care and proposed or realized resilience planning in LMICs. Based on analysis of the included studies, we extracted three key themes to focus resilience-building efforts in emergency units and four accompanying policy recommendations to improve emergency care in the aftermath of climate-related disasters.

Our results corroborate similar reviews on healthcare system resilience. All six foundations of the WHO climate-resilient healthcare systems (WHO, 2015a) were identified in the review, as well as all 16 qualitative attributes in a previous review of resilient healthcare systems (Nuzzo et al., 2019). Challenges confronted by facilities during climate-related disasters parallel components of the WHO hospital emergency response checklist: command and control, communication, safety and security, triage, surge capacity, continuity of essential services, human resources, logistics and supply management, and post-disaster recovery (WHO, 2011).

Despite multiple international frameworks and checklists outlining health system resilience, the review demonstrates a lack of standardization and knowledge of these available tools on behalf of emergency units in LMICs. This may be expected given the nascency in LMIC emergency care system development and lack of dedicated emergency units and providers in many hospitals (Reynolds, Sawe, & Rubiano, 2017). Nonetheless, emergency care plays a vital role in providing everyday emergency care and mitigating the impact of disasters and mass casualty events (WHO, 2019c). Understanding emergency care's role in LMIC health system resilience is further confounded by limited funding for health research, particularly for multidisciplinary topics like climate change and health (Pandve, 2010).

### *Key Themes*

*Resource Allocation.* Securing appropriate resources during surges in demand was a common concern. Emergency care provision is unique in health service delivery not just for ensuring quality but also for acquiring it in a time-sensitive manner—reflecting the nature of emergency care. Essential consumable and non-consumable supplies and associated infrastructure are a precondition for operationalized, full-spectrum emergency services, especially for the most critically ill patients (Reynolds et al., 2017). Severe disasters impact critical resources via disrupted supply chains, hospital evacuations and thus cause loss of healthcare access in the short and long-term (Geiling et al., 2014; Stafford, Morrison, Godfrey, & Mahalu, 2014). During times of scarcity, crisis standards of care (CSC), published by the Institute of Medicine in 2012, offers a systematic approach for practitioners and healthcare systems to follow.

The CSC framework was not included in any articles yet provides ethical principles to guide decision-making and resource allocation in an equitable manner during times of resource constraints (Institute of Medicine [IOM], 2012). The framework assists healthcare systems, in partnership with public health, to plan for and respond to disasters. Strengthening basic emergency care and public health systems preemptively supports disaster and surge events (Geiling et al., 2014) and potentially reduces the need for severe rationing of care. The review emphasized community health workers and public health officials as important to disaster planning and response with strengths well-positioned to link, coordinate, plan, and respond while addressing the needs of vulnerable populations (Banwell, Rutherford, Mackey, & Chu, 2018). As with CSC, public health teams address health disparities in times of scarcity as disasters disproportionately affect the poor and those with disabilities, underlying health conditions, and extremes of age (Davis, Wilson, Brock-Martin, Glover, & Svendsen, 2010; PAHO 2004).

*Health Professional Education.* According to the review, training for emergency care health professionals versed in disaster preparedness and management of emergent conditions was extremely limited. To address this identified gap in local leadership and technical skill, Ministries of Health should expand the health workforce with specialty-trained emergency care providers across all cadres to be able to provide robust everyday emergency care. WHO has created an open-access course called the Basic Emergency Care Course to provide clear technical guidance for emergency care in resource-limited settings (WHO & ICRC, 2018). All authors supported enhanced coordination of healthcare facilities to increase adaptive capacity and address local disaster threats. Healthcare systems should then tailor disaster training applicable to emergency care providers and include scenarios with their own facility plans and disaster risks.

Our findings suggest that climate change perceptions of health professionals do not match the climate science reality of increasing climate-influenced disasters and adverse health effects (Farley et al., 2017; IPCC, 2014). To build resilience in the theme of health professional education, the Global Consortium on Climate and Health Education, which partners with health professions schools (nursing, medicine, public health) and global partnerships to improve climate education, is a valuable resource (Shaman & Knowlton, 2018). Institutions can join as members through Columbia University Mailman School of Public Health and access numerous resources including in other languages. The National Institute of Environmental Health Sciences (NEHS) Climate Change and Human Health Literature Portal also serves as an open-access resource (NIEHS, 2020). Databases such as these offer countries an accessible starting point for global climate change knowledge for health. Search features allow for the specification of geographic location and exposure. As the literal portal library expands, capturing studies on healthcare facilities in LMICs will be crucial for networks, research, and knowledge translation for healthcare providers. It may even serve as a data repository of healthcare facility resilience in the future.

*Infrastructure Development.* This review highlighted multiple opportunities for healthcare facilities and emergency care infrastructure to be strengthened in LMICs despite financial limitations. Infrastructure failures commonly include loss of electricity required for critical services and compromised building integrity causing massive disruptions in critical operations. Opportunities identified to build resilience included patient transport, stockpiles of supplies, and constructing hospitals with resilience to increased climate stress.

Toolkits are available to assist healthcare facilities with building healthcare facility resilience (Balbus et al., 2016). The first is the Pan American Health Organization's Smart Hospital Initiative (SHI) (PAHO, 2017), which promotes resilient (safe), sustainable (smart), and environmentally sound (green) facilities in Latin America and the Caribbean. The framework for health facilities works to build structural, nonstructural, and functional resilience; reduce carbon footprint; and reduce overall environmental footprint. The toolkit has a hospital safety index to assess risk and vulnerability and a green checklist to identify areas of enhanced environmental sustainability. A cost-benefit analysis tool assists decision-makers by identifying and calculating trade-offs of interventions. The second toolkit is the World Bank Group Climate Change and Health Diagnostic (WHO & World Bank Group, 2018), which supports climate-smart healthcare in an effort to reduce greenhouse gas emissions from the health sector and build resilience. The framework connects climate impacts to health and works with communities to develop infrastructure based on targeted health needs.

*Policy Recommendations*

*Strengthen Basic Emergency Care Systems.* Per our review, no standardized, scalable solutions to date have emphasized strengthening basic emergency care systems as a mitigation strategy to reduce the anticipated negative health impacts of climate change. More than 24 million deaths (54 percent of total annual deaths) in LMICs can potentially be addressed by prehospital and facility-based emergency care (Thind, Hsia, Mabweijano, Hicks, & Zakariah, 2015). Opportunities to strengthen emergency care systems exist at multiple points of patient contact with an emergent patient: on the scene, during transportation, during triage, and during care at health facilities. Additionally, emergency care can be strengthened by increasing cooperation and sharing of knowledge between and across sectors that support healthcare delivery—transportation, energy, and water management. While not directly addressed in this review, emergency medical services (EMS) development is part of strengthening emergency care systems as it provides an opportunity to improve resource utilization and reduce time to critical interventions (Wachira & Smith, 2013). Enhancing and investing in emergency care during normal operations is crucial to prevent unmanageable impacts when disasters occur and to care for patients currently being impacted by climate change as well as routine medical conditions (Carlson et al., 2019).

*Invest in Quality Research.* As revealed by this review, there is a dearth of research on building healthcare facility resilience toward the harms of a changing climate, specifically in low-resource settings. Low cost, clearly defined interventions to strengthen emergency care systems have immense potential for enhancing capacity and the delivery of quality care in resource-scarce settings (Moresky et al., 2019). Trained health professionals and scientists, including social and behavioral researchers, can prioritize systems-based projects to strengthen weaknesses and mobilize resources for climate-smart, efficient healthcare service delivery. Likewise, engineers and modelers can integrate 21st-century technologies and tools into accurate risk and vulnerability predictions for better healthcare preparedness and rapid, actionable public health responses for all people in all places regardless of socioeconomic status, race or ethnicity, age, or underlying medical conditions. Recognizing the connection between physical infrastructure and community resilience during disasters, engineers developed a framework that incorporates the built environment within a community network (Cimellaro, Paolo, Renschler, Reinhorn, & Arendt, 2016). Healthcare facility resilience should be integral to community climate resilience.

*Increase Funding for Climate-Smart Health Care.* Financial barriers in LMICs too often limit interventions, even with a projected high return on investment (Reynolds et al., 2017). It is crucial that LMICs have dedicated international funds and accompanying expert guidance for applying climate science data locally, implementing climate-smart healthcare, updating existing facilities, and monitoring interventions that are essential to improve health outcomes now as well as during climate-related events. Connecting with international organizations such as Health Care Without Harm provides resources and guidance for countries and new donors. The Green Climate Fund is one group that offers grants, loans, and equity for mitigation and adaptation initiatives targeting low-income countries and small island developing states (Green Climate Fund, 2020).

*Identify and Empower Leaders.* Many nations lack the political will and expert leadership necessary for scalable action despite readily available guides and interventions. Country-specific interventions will likely need to begin with local leaders yet can be nurtured and strengthened by dedicated international efforts to form public, private, and academic partnerships. To start, governments in LMICs can appoint a directorate specifically to emergency care delivery (Reynolds et al., 2017) who can guide the strengthening of everyday emergency care systems nationwide, implement training programs and create and implement disaster plans on local and national levels. National policies can also require all new healthcare facilities to be constructed per guidelines focused on mitigation, adaptation, and resilience; these policies can be synergistic with current World Health Organization plans for emergency care system strengthening and the United Nations Sustainable Development Goals and Sendai Framework for Disaster Risk Reduction. Simultaneously, multisectoral involvement is necessary to properly support a successful emergency care system. With a "health first" approach, health can and should be considered at all stages of government decision-making with sectors relevant to health: transportation, energy, agriculture, water. It is under this awareness that multisectoral action can script timely, operational policies for nations assembled for protecting people against physical infrastructure hazards, strain on healthcare systems, and service disruptions to advance climate justice for all people regardless of age, socioeconomic status, race, ethnicity, or underlying health status.

### *Strengths and Limitations*

This study has a few strengths. First, the review used rigorous methods, including the search of four electronic databases in addition to the National Institutes of Environmental Health Sciences Climate Change and Human Health literature portal. Two independent reviewers screened articles, and all reviewers agreed on the final articles. The review comprises seven different countries representing two island nations and countries from the continents of Africa and Asia. Results captured rural and urban acute care settings that are primarily hospitals but also an emergency nutrition coordination unit, illustrating a spectrum of emergency care settings. A diverse group of stakeholders in government, academia, nongovernmental organizations, and the public are represented across studies and surveys. Droughts, floods, hurricanes, wildfires, and other climate disasters are incorporated in the review. Problems address both disaster preparedness and response with a focus on reducing morbidity and mortality, excluding individual health impacts.

Several limitations remain. The scoping review is restricted to English-only literature, which eliminates articles in other languages that would meet inclusion otherwise. The search did not include countries in Central or South America or parts of Europe or studies of low quality, self-reported surveys, thus limiting generalizability and increasing potential for selection and information bias. The search was restricted by using "resilient" or "resilience" per the World Health Organization definition. We believe this language may limit the yield of older studies.

## Conclusion

Now is the time for health systems in LMICs to build resilience against extreme weather events and surges in climate-related health conditions by strengthening emergency care systems. Policies that incorporate climate and health will defend against service disruptions and protect high-quality emergency care as a fundamental right for all, even during times of hardship. A multisector approach to disaster preparedness and international partnerships can further ensure that healthcare resilience is embedded in adaptation planning now and in the future.

**Caitlin Rublee, MD, MPH**, is an assistant professor of emergency medicine in the Department of Emergency Medicine at the Medical College of Wisconsin in Milwaukee, Wisconsin.

**Corey Bills, MD, MPH**, is an assistant professor of emergency medicine in the Department of Emergency Medicine at the University of Colorado School of Medicine in Aurora, Colorado.

**Cecilia Sorensen, MD**, is an instructor in the Department of Emergency Medicine at the University of Colorado School of Medicine in Aurora, Colorado.

**Jay Lemery, MD**, is a professor of emergency medicine in the Department of Emergency Medicine at the University of Colorado School of Medicine in Aurora, Colorado.

**Emilie Calvello Hynes, MD, MPH**, is an associate professor of emergency medicine in the Department of Emergency Medicine at the University of Colorado School of Medicine in Aurora, Colorado.

## Notes

Conflicts of interest: None declared.

**Corresponding author**: Caitlin Rublee, crublee@mcw.edu

## References

Aitken, Peter, Richard Charles Franklin, Jenine Lawlor, Rob Mitchell, Kerrianne Watt, Jeremy Furyk, Niall Small, Leone Lovegrove, and Peter Leggat. 2015. "Emergency Department Presentations Following Tropical Cyclone Yasi." *PLOS One* 10 (6): e0131196.

Balbus, John, Peter Berry, Meagan Brettle, Shalini Jagnarine-Azan, Agnes Soares, Ciro Ugarte, Linda Varangu, and Elena Villalobos Prats. 2016. "Enhancing the Sustainability and Climate Resiliency of Health Care Facilities: A Comparison of Initiatives and Toolkits." *Revista Panamericana de Salud Pública/Pan American Journal of Public Health* 40 (3): 174–80.

Banwell, Nicola, Shannon Rutherford, Brendan Mackey, and Cordia Chu. 2018. "Towards Improved Linkage of Disaster Risk Reduction and Climate Change Adaptation in Health: A Review." *International Journal of Environmental Research and Public Health* 15 (4): 793.

Barbier, Edward B., and Jacob P. Hochard. 2018. "The Impacts of Climate Change on the Poor in Disadvantaged Regions." *Review of Environmental Economics and Policy* 12 (1): 26–47.

Brown, Amal Tucker, and Eric Alain Ategbo. 2017. "Interventions to Build Resilience of the Health System to the El Niño Drought in Ethiopia." *Field Exchange—Emergency Nutrition Network ENN* (No.55): 94–7.

Bucher, Joshua, Jonathan McCoy, Colleen Donovan, Snehal Patel, Pamela Ohman-Strickland, and Asa Dewan. 2018. "EMS Dispatches During Hurricanes Irene and Sandy in New Jersey." *Prehospital Emergency Care* 22 (1): 15–21.

Carlson, Lucas C., Teri A. Reynolds, Lee A. Wallis, and Emilie J. Calvello Hynes. 2019. "Reconceptualizing the Role of Emergency Care in the Context of Global Healthcare Delivery." *Health Policy Plan* 34 (1): 78–82.

Chowdhury, Muhammad Abdul Baker, Andrew J. Fiore, Scott A. Cohen, Clayton Wheatley, Barnard Wheatley, Meenakshi Puthucode Balakrishnan, Michael Chami et al. 2019. "Health Impact of Hurricanes Irma and Maria on St Thomas and St John, US Virgin Islands, 2017-2018." *American Journal of Public Health* 109 (12): 1725–32.

Cimellaro, Gian, Chris Paolo, Andrei M. Renschler, Reinhorn, and Lucy Arendt. 2016. "PEOPLES: A Framework for Evaluating Resilience." *Journal of Structural Engineering* 142 (10): 04016063.

Critical Appraisal Skills Programme. 2020. *CASP Qualitative Checklist 2019* [Online]. https://casp-uk.net/wp-content/uploads/2018/01/CASP-Qualitative-Checklist-2018.pdf. Accessed April 15, 2020.

Davis, Jennifer R., Sacoby Wilson, Amy Brock-Martin, Saundra Glover, and Erik R. Svendsen. 2010. "The Impact of Disasters on Populations With Health and Health Care Disparities." *Disaster Medicine and Public Health Preparedness* 4 (1): 30–8.

Davis, Robert E., and Wendy M. Novicoff. 2018. "The Impact of Heat Waves on Emergency Department Admissions in Charlottesville, Virginia, U.S.A." *International Journal of Environmental Research and Public Health* 15 (7): 1436.

Dennis, Bradley M., David P. Stonko, Rachael A. Callcut, Richard A. Sidwell, Nicole A. Stassen, Mitchell J. Cohen, Bryan A. Cotton, and Oscar D. Guillamondegui. 2019. "Artificial Neural Networks Can Predict Trauma Volume and Acuity Regardless of Center Size and Geography: A Multicenter Study." *Journal of Trauma and Acute Care Surgery* 87 (1): 181–87.

Diffenbaugh, Noah S., and Marshall Burke. 2019. "Global Warming Has Increased Global Economic Inequality." *Proceedings of the National Academy of Sciences of the United States of America* 116 (20): 9808–13.

Doran, Kelly M., Ryan P. McCormack, Eileen L. Johns, Brendan G. Carr, Silas W. Smith, Lewis R. Goldfrank, and David C. Lee. 2016. "Emergency Department Visits for Homelessness or Inadequate

Housing in New York City Before and After Hurricane Sandy." *Journal of Urban Health* 93 (2): 331–44.

Farley, Jessica M., Inoka Suraweera, W. L. S. P. Perera, Jeremy Hess, and Kristie L. Ebi. 2017. "Evaluation of Flood Preparedness in Government Healthcare Facilities in Eastern Province, Sri Lanka." *Global Health Action* 10 (1): 1331539.

Friel, Sharon, Kathryn Bowen, Diarmid Campbell-Lendrum, Howard Frumkin, Anthony J. McMichael, and Kumanan Rasanathan. 2011. "Climate Change, Noncommunicable Diseases, and Development: The Relationships and Common Policy Opportunities." *Annual Review of Public Health* 32: 133–47.

Geiling, James, Frederick M. Burkle, Jr., Dennis Amundson, Guillermo Dominguez-Cherit, Charles D. Gomersall, Matthew L. Lim, Valerie Luyckx et al. 2014. "Resource-Poor Settings: Infrastructure and Capacity Building: Care of the Critically Ill and Injured During Pandemics and Disasters: CHEST Consensus Statement." *Chest* 146 (4 Suppl.): e156S–67S.

Ghazali, Daniel, Maximilien Guericolas, Frederic Thys, Francois Sarasin, Pedro Arcos Gonzalez, and Enrique Casalino. 2018. "Climate Change Impacts on Disaster and Emergency Medicine Focusing on Mitigation Disruptive Effects: an International Perspective." *International Journal of Environmental ResearchandPublic Health* 15 (7): 1–13.

Green Climate Fund. 2020. *Projects and Programmes* 2020 [Online]. Available from https://www.greenclimate.fund/what-we-do/projects-programmes. Accessed April 11, 2020.

Guyatt, Gordon H., Andrew D. Oxman, Holger J. Schunemann, Tugwell, Peter, & Knottnerus, Andre et al. 2011. "GRADE Guidelines: A New Series of Articles." *Journal of Clinical Epidemiology* 64 (4): 380–82.

Hess, Jeremy J., Shubhayu Saha, and George Luber. 2014. "Summertime Acute Heat Illness in U.S. Emergency Departments From 2006 Through 2010: Analysis of a Nationally Representative Sample." *Environmental Health Perspectives* 122 (11): 1209–15.

Hsiang, Solomon M., Marshall Burke, and Edward Miguel. 2013. "Quantifying the Influence of Climate on Human Conflict." *Science* 341 (6151): 1235367.

Hutchinson, Justine A., Jason Vargo, Meredith Milet, Nancy H.F. French, Michael Billmire, Jeffrey Johnson, and Sumi Hoshiko. 2018. "The San Diego 2007 Wildfires and Medi-Cal Emergency Department Presentations, Inpatient Hospitalizations, and Outpatient Visits: An Observational Study of Smoke Exposure Periods and a Bidirectional Case-Crossover Analysis." *PLOS Med* 15 (7): e1002601.

Institute of Medicine (IOM). *Crisis Standards of Care: A Systems Framework for Catastrophic Disaster Response*. 2012. Washington DC: The National Academies Press. p. 1-31.

Intergovernmental Panel on Climate Change (IPCC). 2014. "Climate Change 2014: Synthesis Report." In *Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. Core Writing Team, R. K. Pachauri, L. Meyer. Geneva: Switzerland. 1-169.

Kanzaria, Hemal K., Marc A. Probst, and Renee Y. Hsia. 2016. "Emergency Department Death Rates Dropped By Nearly 50 Percent, 1997-2011." *Health Affairs (Millwood)* 35 (7): 1303–8.

Kironji, Antony Gatebe, Peter Hodkinson, Sarah Stewart de de Ramirez, Trisha Anest, Lee Wallis, Junaid Razzak, Alexander Jenson, and Bhakti Hansoti. 2018. "Identifying Barriers for Out of Hospital Emergency Care in Low and Low-Middle Income Countries: A Systematic Review." *BMC Health Services Research* 18 (1): 291.

Koka, Philip M., Hendry R. Sawe, Khalid R. Mbaya, Said S. Kilindimo, Juma A. Mfinanga, Victor G. Mwafongo, Lee A. Wallis, and Teri A. Reynolds. 2018. "Disaster preparedness and response capacity of regional hospitals in Tanzania: a descriptive cross-sectional study." *BMC Health Services Research* 18 (1): 835.

Kulp, Scott A., and Benjamin H. Strauss. 2019. "New Elevation Data Triple Estimates of Global Vulnerability to Sea-Level Rise and Coastal Flooding." *Nat Commun* 10 (1): 4844.

Lee, David C., Silas W. Smith, Brendan G. Carr, Kelly M. Doran, Ian Portelli, Corita R. Grudzen, and Lewis R. Goldfrank. 2016. "Geographic Distribution of Disaster-Specific Emergency Department Use After Hurricane Sandy in New York City." *Disaster Medicine and Public Health Preparedness* 10 (3): 351–61.

Levy, Barry S., and Jonathan A. Patz. 2015. "Climate Change, Human Rights, and Social Justice." *Annals of Global Health* 81 (3): 310–22.

Levy, Barry S., Victor W. Sidel, and Jonathan A. Patz. 2017. "Climate Change and Collective Violence." *Annual Review of Public Health* 38: 241–57.

Liang, Stephen Y., and Nicole Messenger. 2018. "Infectious Diseases After Hydrologic Disasters." *Emergency Medicine Clinics of North America* 36 (4): 835–51.

Malik, Sidrah, David C. Lee, Kelly M. Doran, Corita R. Grudzen, Justin Worthing, Ian Portelli, Lewis R. Goldfrank, and Silas Smith. 2018. "Vulnerability of Older Adults in Disasters: Emergency Department Utilization by Geriatric Patients After Hurricane Sandy." *Disaster Medicine and Public Health Preparedness* 12 (2): 184–93.

McQuade, Linda, Barry Merriman, Mark Lyford, Bella Nadler, Sangeeta Desai, Roger Miller, and Samuel Mallette. 2018. "Emergency Department and Inpatient Health Care Services Utilization by the Elderly Population: Hurricane Sandy in The State of New Jersey." *Disaster Medicine and Public Health Preparedness* 12 (6): 730–38.

Moresky, Rachel T., Junaid Razzak, Teri Reynolds, Lee A. Wallis, Benjamin W. Wachira, Mulinda Nyirenda, and Waldemar A. Carlo et al. 2019. "Advancing Research on Emergency Care Systems in Low-Income and Middle-Income Countries: Ensuring High-Quality Care Delivery Systems." *BMJ Global Health* 4 (Suppl. 6): e001265.

Natuzzi, Eileen S., Cynthia Joshua, Matthew Shortus, Reginald Reubin, Tenneth Dalipanda, Karen Ferran, Audrey Aumua, and Stephanie Brodine. 2016. "Defining Population Health Vulnerability Following an Extreme Weather Event in an Urban Pacific Island Environment: Honiara, Solomon Islands." *American Journal of Tropical Medicine and Hygiene* 95 (2): 307–14.

NIEHS. 2020. *Climate Change and Human Health Literature Portal* [Online]. https://tools.niehs.nih.gov/cchhl/

Nuzzo, Jennifer B., Diane Meyer, Michael Snyder, Sanjana J. Ravi, Ana Lapascu, Jon Souleles, Carolina I. Andrada, and David Bishai. 2019. "What Makes Health Systems Resilient Against Infectious Disease Outbreaks and Natural Hazards? Results From a Scoping Review." *BMC Public Health* 19 (1): 1310.

Obermeyer, Ziad, Samer Abujaber, Maggie Makar, Samantha Stoll, Stephanie R. Kayden, Lee A. Wallis, Teri A. Reynolds, and Consortium Acute Care Development. 2015. "Emergency Care in 59 Low- and Middle-Income Countries: A Systematic Review." *Bulletin of theWorld Health Organization* 93 (8): 577–86G.

Obradovich, Nick, Robyn Migliorini, Martin P. Paulus, and Iyad Rahwan. 2018. "Empirical Evidence of Mental Health Risks Posed by Climate Change." *Proceedings of the National Academy of Sciences of the United States of America* 115 (43): 10953–58.

Padhy, Susanta Kumar, Sidharth Sarkar, Mahima Panigrahi, and Surender Paul. 2015. "Mental Health Effects of Climate Change." *Indian Journal of Occupational and Environmental Medicine* 19 (1): 3–7.

Pan American Health Organization (PAHO). 2004. *Management of Dead Bodies in Disaster Scenarios*, Washington, DC.

Pan America Health Organization (PAHO). 2017. *Smart Hospitals Toolkit*, Washington DC.

Pandve, Harshal T. 2010. "Climate Change and Health: Research Challenges for Health in the Developing Countries." *Indian Journal of Occupational and Environmental Medicine* 14 (2): 42–4.

Patz, Jonathan A., Gibbs Holly K., Jonathan A. Foley, Rogers Jamesine V., Smith Kirk R. 2007. "Climate Change and Global Health: Quantifying a Growing Ethical Crisis." *EcoHealth* 4 (4): 397–405.

Pruss-Ustiun, Annette, Emilie van van Deventer, Pierpaolo Mudu, Diarmid Campbell-Lendrum, Carolyn Vickers, Ivan Ivanov, Francesco Forastiere et al. 2019. "Environmental Risks and Non-Communicable Diseases." *BMC* 364: 17–9.

Reynolds, Teri A., Hendry Sawe, Andres M. Rubiano, Shin, Sang Do, Wallis, Lee, & Mock, Charles et al. 2017. *Chapter 13 Strengthening Health Systems to Provide Emergency Care*, 3rd ed. Washington, DC: The International Bank for Reconstruction and Development/The World Bank.

Shaman, Jeffrey, and Kim Knowlton. 2018. "The Need for Climate and Health Education." *American Journal of Public Health* 108 (S2): S66–S7.

Shanahan, Thomas, Nicholas Risko, Junaid Razzak, and Zulfiqar Bhutta. 2018. "Aligning Emergency Care With Global Health Priorities." *International Journal of Emergency Medicine* 11 (1): 52.

Siman-Tov, Maya, Irina Radomislensky, Israel Trauma Group, and Kobi Peleg. 2013. "Reduction in Trauma Mortality in Israel During the Last Decade (2000-2010): The Impact of Changes in the Trauma System." *Injury* 44 (11): 1448–52.

Stafford, Renae E., Catherine A. Morrison, Godwin Godfrey, and William Mahalu. 2014. "Challenges to the Provision of Emergency Services and Critical Care in Resource-Constrained Settings." *Global Heart* 9 (3): 319–23.

Sukhralia, Shivani, Mansi Verma, Shruthi Gopirajan, P. S. Dhanaraj, Rup Lal, Neeti Mehla, and Chhaya Ravi Kant. 2019. "From Dengue to Zika: The Wide Spread of Mosquito-Borne Arboviruses." *European Journal of Clinical Microbiology & Infectious Diseases* 38 (1): 3–14.

Tallon, John M., Deshayne B. Fell, Saleema A. Karim, Stacy Ackroydstolarz, & Petrie, David. 2012. "Influence of a Province-Wide Trauma System on Motor Vehicle Collision Process of Trauma Care and Mortality: A 10-Year Follow-up Evaluation." *Canadian Journal of Surgery* 55 (1): 8–14.

Tang, Ning, John Stein, Renee Y. Hsia, Judith H. Maselli, and Ralph Gonzales. 2010. "Trends and Characteristics of US Emergency Department Visits, 1997-2007." *JAMA* 304 (6): 664–70.

The World Bank. 2020. *World Bank Country and Lending Groups* [Online]. June 2019 2020. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups. Accessed April 14, 2020.

Thind, Amardeep, Renee Hsia, Jackie Mabweijano, Eduardo Hicks, Ahmed Zakariah, Charles N. Mock. 2015. "Prehospital and Emergency Care." In *Disease Control Priorities*, ed. Haile T. Debas, Peter Donkor, Atul Gawande, Dean Jamison, Margaret Kruk, and Charles N. Mock. Vol. 9. Washington, DC: World Bank. 245-262.

United Nations. 2015. "Sendai Framework for Disaster Risk Reduction 2015-2030."

Van Minh, Hoang, Tran Tuan Anh, Joacim Rocklov, Kim Bao Giang, Le Quynh Trang, Klas-Goran Sahlen, Maria Nilsson, and Lars Weinehall. 2014. "Primary Healthcare System Capacities for Responding to Storm and Flood-Related Health Problems: A Case Study From a Rural District in Central Vietnam." *Global Health Action* 7: 23007.

Wachira, Benjamin, and Wayne Smith. 2013. "Major Incidents in Kenya: The Case for Emergency Services Development and Training." *Prehospital and Disaster Medicine* 28 (2): 170–73.

Waits, Audrey, Anastasia Emelyanova, Antti Oksanen, Khaled Abass, and Arja Rautio. 2018. "Human Infectious Diseases and the Changing Climate in the Arctic." *Environment International* 121 (Pt 1): 703–13.

Watts, Nick, Markus Amann, Nigel Arnell, Sonja Ayeb-Karlsson, Kristine Belesova, Maxwell Boykoff, Peter Byass et al. 2019. "The 2019 Report of The Lancet Countdown on Health and Climate Change: Ensuring That the Health of a Child Born Today is Not Defined by a Changing Climate." *The Lancet* 394 (10211): 1836–78.

World Health Organization (WHO). 2011. *Hospital Emergency Response Checklist*, Denmark.

World Health Organization (WHO). 2015a. *Operational Framework for Building Climate Resilient Health Systems*. Geneva: WHO.

World Health Organization (WHO). 2015b. *Strengthening Health Resilience to Climate Change*. Technical Briefing. Geneva: Switzerland. 1–24.

World Health Organization (WHO). 2018. *Malnutrition* [Online]. February 16. https://www.who.int/en/news-room/fact-sheets/detail/malnutrition. Accessed April 1, 2020.

World Health Organization (WHO). 2019a. *Emergency and Trauma Care*.

World Health Organization (WHO). 2019b. *Emergency and Trauma Care* [Online]. https://www.who.int/emergencycare/emergencycare_infographic/en/. Accessed February 2, 2020.

World Health Organization (WHO). 2019c. *Resolution WHA 72.16: Emergency Care Systems for Universal Health Coverage: Ensuring Timely Care for the Acutely Ill and Injured*. Geneva: World Health Assembly.

World Health Organization (WHO) and International Committee of the Red Cross (ICRC). 2018. *Basic Emergency Care: Approach to the Acutely Ill and Injured*. World Health Organization and the International Committee of the Red Cross. Geneva: Switzerland.

World Health Organization (WHO) and Pan American Health Organization (PAHO). 2015. *Hospital Safety Index: Guide for Evaluators*. WHO.

World Health Organization (WHO). and World Bank Group. 2018. *Methodological Guidance Climate Change and Health Diagnostic: A Country-Based Approach for Assessing Risks and Investing in Climate-Smart Health Systems*. Washington, DC.

Wu, Xiaoxu, Yongmei Lu, Sen Zhou, Lifan Chen, and Bing Xu. 2016. "Impact of Climate Change on Human Infectious Diseases: Empirical Evidence and Human Adaptation." *Environment International* 86: 14–23.

Zakrison, Tanya L, Davel Milian Valdes, and James M. Shultz. 2020. "The Medical, Public Health, and Emergency Response to the Impact of 2017 Hurricane Irma in Cuba." *Disaster Medicine and Public Health Preparedness* 14 (1): 10–7.

Zhong, Shuang, Xiang Yu Hou, Michele Clark, Yu-Li Zang, Lu Wang, Ling-Zhong Xu, and Gerard FitzGerald. 2014. "Disaster Resilience in Tertiary Hospitals: A Cross-Sectional Survey in Shandong Province, China." *BMC Health Services Research* 14: 135.

World Medical and Health Policy



# Carceral and Climate Crises and Health Inequities: A Call for Greater Transparency, Accountability, and Human Rights Protections

**Cynthia A. Golembeski, Kimberly R. Dong, and Ans Irfan**

*The United States has approximately 5 percent of the world's population but incarcerates nearly 25 percent of the world's incarcerated population and produces nearly 25 percent of global carbon dioxide emissions. Climate change and hyperincarceration are causes and consequences of structural racism and economic deprivation, which disproportionately affect structurally disenfranchised citizens, including lower-income communities, communities of color, and people with disabilities. Empirical evidence exists regarding the adverse health effects of climate change and mass incarceration, which occur in cascading and overlapping categories and include preventable death, illness, and injury. Researchers underscore the medical vulnerability of incarcerated populations, who are increasingly susceptible to climate-driven exposure pathways and mental and physical health outcomes involving extreme temperatures, natural disasters, infectious diseases, and displacement. Intersectional structural drivers, such as anthropogenic climate change and hyperincarceration, undermine social and political determinants of health equity. Policymakers and health professionals can advance understanding and mitigate present and anticipated public health threats by increasing transparency, accountability, and human rights protections with an emphasis on decarceration and decarbonization.*

**KEY WORDS:** climate change, disaster, incarceration

## Marcia Powell and Prison-Attributable Death

Marcia Powell, a 48-year-old woman serving a 2-year sentence for charges related to sex work at an Arizona state prison, was kept in an uncovered chain-linked outdoor cell for at least 4 hours and exposed to temperatures above 107°F in May 2009 (Maricopa County Office of the Medical Examiner, 2009; Wahab & Panichelli, 2013). Arizona prison policy limits this type of confinement to 2 hours. Powell, like many others, would have been better suited for a diversion program with social services as an alternative to incarceration (Wahab & Panichelli, 2013). The county medical examiner report documented a core temperature of 108°F; first and second-degree burns on her face, upper body, chest, legs, and arms; dehydration; metabolic acidosis with coagulopathy; rhabdomyolysis and acute renal failure; plus that she "died as a result of complications of hyperthermia due to environmental heat exposure" (Maricopa County Office of the Medical Examiner, 2009). Yet, the medical examiner ruled the manner of death an accident. Neither individual employees nor the state correctional



doi: 10.1002/wmh3.382

system were held accountable for Powell's painful, unnecessary death despite incarcerated people constituting the only group with a constitutional guarantee to health care and protection from physical and psychological harm under the eighth amendment (Dolovich, 2009; Wahab & Panichelli, 2013).

Despite the lack of systematic surveillance, tracking, and reporting of deaths in jails and prisons due to extreme temperature exposure, unrelated to faulty heating or cooling systems or climate-related disasters, numerous cases are described primarily within court documents, gray literature, and the media (Motanya & Valera, 2016; Prins and Story, 2020; Skarha, Peterson, Rich, & Dosa, 2020).[1] Moreover, jail and prison subpopulations, especially sensitive to higher temperatures, include individuals who are aging, experiencing certain health conditions, as well as taking medications that interfere with the body's capacity to regulate temperature, such as psychotropic and blood pressure drugs (Skarha et al., 2020). Given the numerous people with comorbid mental and physical health conditions who are involved with the criminal legal system, addressing how medications may increase health risks associated with extreme temperature exposure is key (Bark, 1998; Bouchama et al., 2007; Martin-Latry et al., 2007). For instance, Powell's toxicology report includes positive tests for many medications, including Benztropine for Parkinson's disease, the antipsychotic medication Haloperidol, valproic acid, a mood-stabilizing drug used to treat depression and epilepsy, and lidocaine. Benztropine, Haloperidol, and valproic acid are all psychotropic drugs.

Powell exemplifies what Homer Venters, former chief medical officer of the New York City Jails, conceptualizes as a jail or prison attributable death (Venters, 2019).[2] Recent scholarship outlines how incarcerated populations and staff may become increasingly vulnerable to climate-driven health effects associated with extreme temperatures, natural disasters, mental and physical health conditions, and forced displacement (Holt, 2015; Motanya & Valera, 2016; Prins & Story, 2020; Skarha et al., 2020). Although decarceration should be prioritized, despite the urgent need, limited climate adaptation efforts at jails and prisons, including poor emergency management planning after natural disasters, make it difficult to precisely track mortality associated with extreme cold and heat exposure, given that many health conditions are affected by extreme temperatures (Skarha et al., 2020). Without appropriate oversight, accountability, and transparency, it is difficult to empirically assess the number of climate-related illnesses, injuries, and deaths occurring within the criminal legal system (Figure 1).

## Introduction

Public health and legal professionals have laid bare the vast inequities associated with climate change adaptation response, particularly in terms of the social-structural drivers that exacerbate adverse experiences of hyperincarceration, climate change, and associated negative health conditions (Holt, 2015; Motanya & Valera, 2016; Prins & Story, 2020; Skarha et al., 2020).[3],[4] The U.S. has approximately 5 percent of the world's population, yet comprises nearly 25 percent of the world's incarcerated population. Also, the U.S. is responsible for nearly 25 percent of

Figure 1 "Lord" Bones, 72. Incarcerated in Angola, also known as the Louisiana State Penitentiary, takes care of the horses and drives the hearse when burying people who have died while in prison. ("Angola" is the largest maximum-security prison in the U.S. housing nearly 65,000 men as well as the execution chamber for both men and women. "Angola," the name of the former plantation that was in the same area was named after the African country from which many slaves came to Louisiana. "I know I'm blessed. All my troubles, I put them in the Lord's hands. I don't get mad. I take it a day at a time. While you're in here, life is still going on. You've got to make the best of it where you're at. I take pride in what I do. When I go to driving [the hearse], I'm working for the Lord. I'm bringing his children home. Everyone here's inmates just like me. All us got to die and that's something I don't worry about. One day, someone's gonna have to drive me." Photo Credit: Ron Levine, Prisoners of Age).

cumulative carbon dioxide ($CO_2$) emissions to date (refer to Figures 2 and 3).[5],[6] As depicted in Figure 2, the U.S. has emitted approximately 400 billion metric tons of $CO_2$ since the mid-18th century, which is twice that of China and also twice that of the European Union's 28 countries. The U.S. surpassed Europe as a major $CO_2$ emitter during the industrial era. World Prison Brief data (2020) represented in Figure 3 depict the U.S. (655/100,000) as having approximately 2.3 million of the 10.74 million people held in prisons worldwide. Over the past 40 years, the U.S. incarceration rate has increased by over 500 percent, whereas the U.S. cumulative $CO_2$ emissions have increased by over 100 percent. The U.S. has largely abdicated its responsibility to mitigate greenhouse gas emissions or adapt its systems, such as jails and prisons, to the changing climate. Decarceration and decarbonization are key priorities to alleviating suffering, plus reducing health inequities endemic to the political economy of racial capitalism (Story & Prins, 2019).

Health inequities are profoundly influenced by economic deprivation and structural racism, which "refers to the totality of ways in which societies foster racial discrimination through mutually reinforcing systems of housing, education, employment, earnings, benefits, credit, media, health care, and criminal justice" (Bailey et al., 2017, p. 1453). Ruth Wilson Gilmore's definition of racism aptly applies to both carceral and climate injustices, involving "state-sanctioned or extra-legal production and exploitation of group differentiated vulnerability to premature death" (Gilmore, 2007). Public health and criminology experts

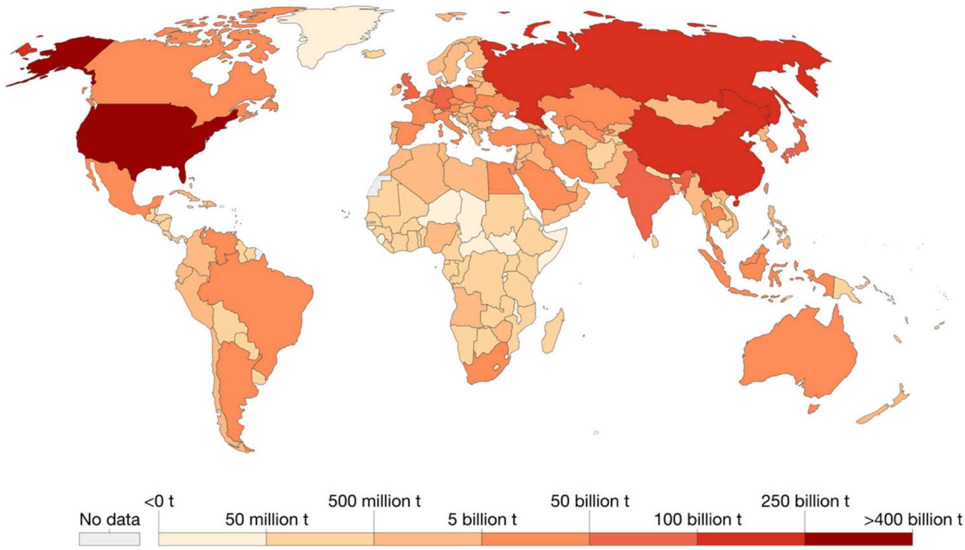



Figure 2 Cumulative $CO_2$ Emissions, 2018. Cumulative $CO_2$ emissions represent the total sum of $CO_2$ emissions produced from fossil fuels and cement since 1751, and is measured in tonnes.
*Source*: Reproduced from Our World in Data. Global Carbon Project (GCP); Carbon Dioxide Information Analysis Centre (CDIAC). https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions (Ritchie & Roser, 2017).

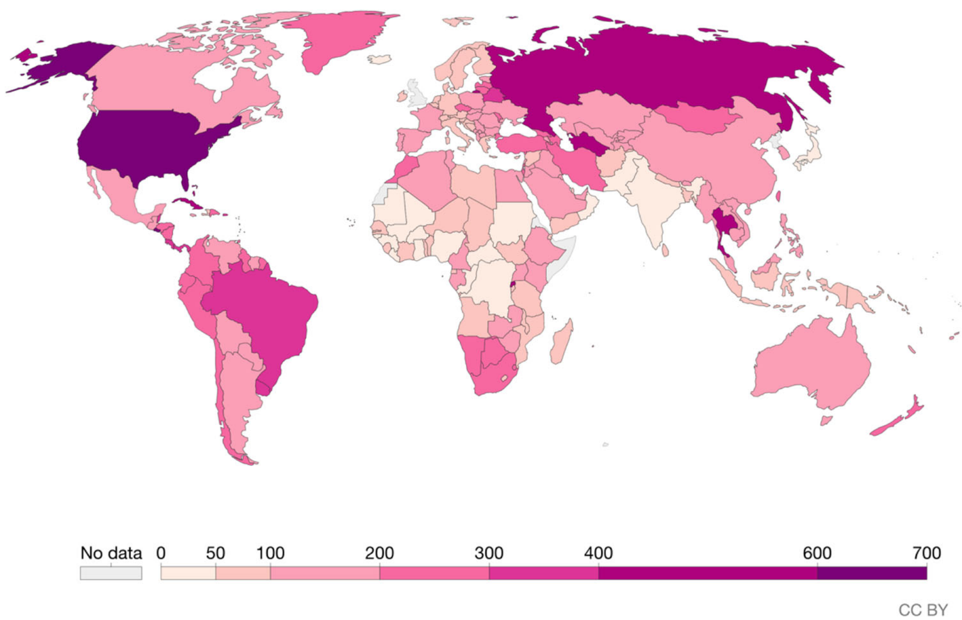



Figure 3 Prison Population Rate Per 100,000, 2018. *Source*: World Prision Brief (2020). Reproduced from Our World in Data. https://ourworldindata.org/grapher/prison-population-rate.

advocate for substantive criminal legal system reform and underscore how many systems of oppression, such as sexism, racism, and classism, are germane to environmental exploitation (Barnert, Ahalt, & Williams, 2020; Cole & Foster, 2001; Nowotny, Bailey, Omori, & Brinkley-Rubinstein, 2020; Tuana, 2019; Venters, 2020). Fundamental causes of hyperincarceration, climate crisis, and related health inequities are linked to "systems of extraction, exploitation, domination, racism, and heteropatriarchy" against which there has been much "intersectional social and political mobilization" and contestation (Prins & Story, 2020). Additionally, policy and scientific experts encourage cross-sectoral collaboration, including community perspectives and embodied expertise, to support democratic governance, address the climate change crisis, and increase equity and positive health outcomes (Krieger, 2020; Méndez, 2020).

> *For those of us in public health, one way to contribute our skills and insights to the changes so urgently needed—in both society overall and the institutions where we work—is to start by respecting the leadership of the myriad groups in coalition, nationally and locally, who are together propelling the current social movement, such as the Movement for Black Lives, the Poor People's Campaign, and the Green New Deal (Krieger, 2020, p. e3).*

Krieger (2020) underscores the lack of reliable, transparent data associated with the health effects of climate change and the criminal legal system, particularly for lesser-resourced social groups. Moreover, political interests seeking to undermine rights and disenfranchise people of color and economically deprived people converge around the public health crises associated with hyperincarceration and climate change (Hertel-Fernandez, 2019; Kamarck, 2019). In terms of carceral and climate contexts, "racism influences health directly through shaping environmental and institutional conditions and practices and through intermediate and proximate factors that impact health outcomes" (Thorpe, Norris, Beech, & Bruce, 2019, p. 209). Additionally, Bowen and Murshid (2016) propose that trauma-informed policy analysis is ideal for addressing social problems, including violence, homelessness, addiction, and chronic disease, all of which are strongly associated with the twin stressors of hyperincarceration and climate injustice.

## Climate Change and Health Inequities

Climate change refers to long-term changes in weather patterns across the globe due to anthropogenic causes, such as fossil fuel use, while global warming—one of many components of the changing climate—refers to the increasing average temperature of Earth's surface (Conway, 2008; Stott, 2016). Although media, the broader public, and even some scientists use the terms "global warming" and "climate change" interchangeably, climate change is a more accurate term for the overall phenomenon.[7] Few issues within the scientific community enjoy the level of consensus as anthropogenic climate change. Nearly 97 percent of scientists agree that climate change is happening and caused by human activity (Cook et al., 2016).

Leading organizations, such as the American Public Health Association (APHA) and the American Medical Association (AMA), concur that anthropogenic climate change exists and emphasize related health challenges. According to the APHA, "climate change poses major threats to human health, human and animal populations, ecological stability, and human social, financial, and political stability and well-being" (American Public Health Association, 2015). Furthermore, the AMA supports "the findings of the Intergovernmental Panel on Climate Change's fourth assessment report and concurs with the scientific consensus that the Earth is undergoing adverse global climate change and that anthropogenic contributions are significant (American Medical Association, 2019)."

Climate change affects the Earth's geophysical systems and perpetuates health inequities (Mora et al., 2017). The U.S. Global Change Research Program (USGCRP)'s Climate and Health Assessment documents the health impacts of climate change in detail (U.S. Global Change Research Program, 2016). Figure 4 illustrates several of the climate drivers, the exposure pathways, and the eventual health outcomes related to such climatic changes. Climate change also exacerbates morbidity and mortality related to heat, air pollution, water and vector-borne disease, malnutrition and food safety, and mental health challenges, and increases disease burdens related to asthma, Alzheimer's disease, chronic obstructive

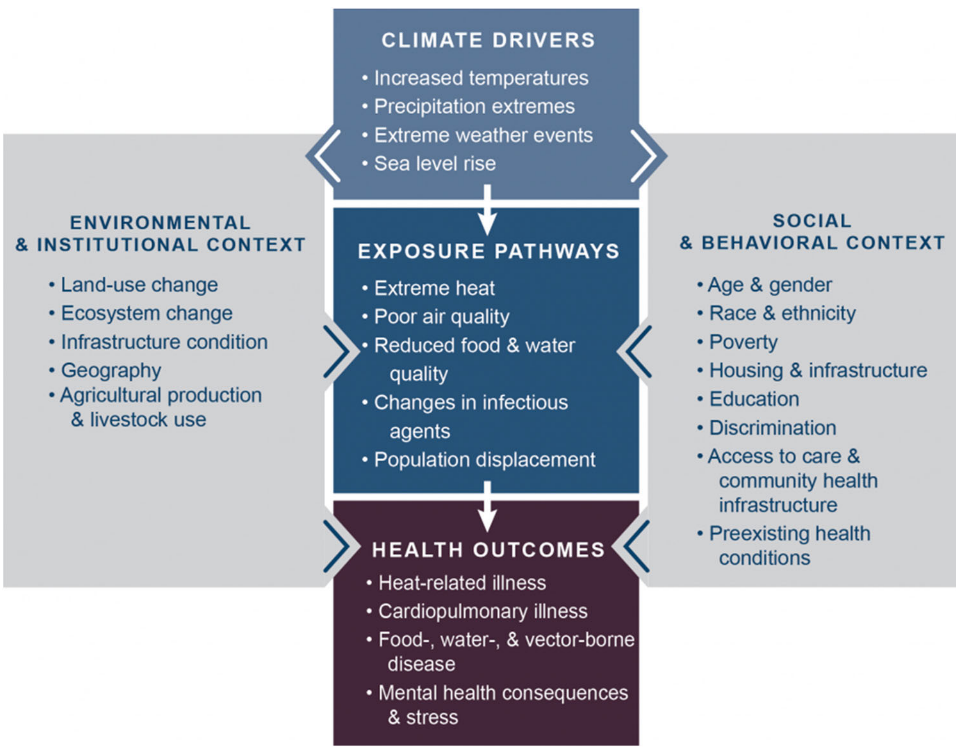



Figure 4 Climate Change and Health. Source: Reproduced from the U.S. Global Change Research Program (USGCRP) Climate and Health Assessment (U.S. Global Change Research Program, 2016). https://health2016.globalchange.gov/downloads.

pulmonary disease, diabetes, cardiovascular disease, obesity, among other conditions (U.S. Global Change Research Program, 2016; Watts et al., 2018). Relatedly, heat exhaustion, heat cramps, and heat stroke interfere with physical and mental functioning (Mayo Clinic, 2020). *Escherichia coli* and dysentery, along with other diseases and infections associated with the stomach, intestine, or other internal organs, are also highly correlated with adverse climate conditions and extreme heat (U.S. Global Change Research Program, 2016; Watts et al., 2018). Climate change adaptation is necessary to avoid exacerbation of chronic disease and mortality rates (Mora et al., 2017; Noble et al., 2014).

Amidst global warming, future health concerns loom large given the increase in temperatures and pollution, including airborne toxins and water-borne infections, associated with fossil fuel use and $CO_2$ emissions (Trumble & Finch, 2019). Ongoing research suggests climate change exacerbates air pollution's ill effects on social welfare, behavior, and cognition in ways that may not yet be fully understood (Herrnstadt, Heyes, Muehlegger, & Saberian, 2020; Mayo Clinic, 2020; Park, Goodman, & Behrer, 2020). Systematically assessing the various chemicals polluting the environment and exposure effects is challenging; therefore, related social costs may be greater than currently anticipated (Herrnstadt et al., 2020; Trumble & Finch, 2019; Vermeulen, Schymanski, Barabási, & Miller, 2020).

Climate change will incur further rising temperatures and extreme weather events increasing in severity, frequency, duration, and unpredictability (Banholzer et al., 2014; Holt, 2015; National Aeronautics and Space Administration [NASA], 2020; Stott, 2016). Moreover, Sze (2020) traces how environmental injustices manifest across racial and economic lines and underscores how environmental justice movements have mitigated multilevel and intersecting injustices. Multiple scales of social, economic, historical, and political factors influence differential human vulnerability to environmental hazards and harms (Thomas et al., 2019). Drastic actions to reduce greenhouse gas emissions, the root cause of climate change, and climate change-related human activities are critical.[8] Global inaction and a lack of leadership on climate change mitigation and adaptation have serious climate and environmental justice consequences (Gore, 2006; Méndez, 2020).

## Hyperincarceration and Health Inequities

Western (2018) posits racial inequality, poverty, and a high level of violence as three primary characteristics of the social world of hyperincarceration. Seminal works analyze discrimination and the political and sociohistorical antecedents of hyperincarceration, including the Black Codes, as a social determinant of health (Acker et al., 2019; Alexander, 2012; Davis, 2020; Fullilove, 1993; Hinton, 2016; Muhammad, 2010). Hyperincarceration and negative individual and population-level public health effects, along with structural violence at its core, have been well documented (Golembeski & Fullilove, 2008; Golembeski et al., 2020b; Gottschalk, 2015; Patterson, 2013; Venters, 2019; Wacquant, 2009). Paradoxically, there is evidence that some jails or prisons may provide quality care and healing, which underscores the withering health and social safety nets in lesser-resourced communities (Massoglia & Remster, 2019; Sufrin, 2017).

Currently, more than 2,000 prisons and 3,000 jails hold approximately 2.3 million people (Carson, 2020; Flagg & Neff, 2020). Over 60 percent of people in prison are people of color (Carson, 2020). Scholars have posited involvement with the criminal legal system as a cause and a consequence of poverty (Sugie, 2012; Western, 2018).[9] The U.S. criminal legal system has been drawn upon to address many social problems and public health concerns, including mental health and substance use challenges, violence, and poverty. Racial disproportionality in arrest, detention, solitary confinement, and jail and prison attributable injury, illness, and death rates have been empirically reported (Rosenberg et al., 2017; Massoglia, 2008; Venters, 2019). Massoglia and Pridemore (2015) underscore the higher rates of exposure to the carceral system and related consequences, which may serve as both acute and chronic stressors, befalling people of color, those living with disabilities, and the economically deprived.

Nearly 95 percent of people incarcerated return to neighborhoods and face reentry challenges associated with family reunification, health care, housing, and financial security due to structural issues (Golembeski & Fullilove, 2008). Incarceration rates may be declining for certain populations, yet the criminal legal system's effects on individuals, families, and communities remain long after incarceration. For instance, people convicted of a felony and misdemeanor violations face over 44,000 restrictions, barriers, and bans limiting access to health care, public benefits, food, housing, education, employment, and other rights (Golembeski, Irfan, & Dong, 2020a; Kirk & Wakefield, 2018; U.S. Commission on Civil Rights [USCCR], 2019).[10] These 44,000 "collateral consequences" of punishment may increase incentives to recidivate, decrease successful reintegration, and exacerbate health inequities (Chesney-Lind & Mauer, 2003; USCCR, 2019).

Figure 5 underscores structural racism and economic deprivation as endemic to the cyclical nature of incarceration and discrimination as outlined in this section (Acker et al., 2019). People involved with the criminal legal system disproportionately face significant health challenges during periods of time before, during, and after incarceration (Acker et al., 2019; Cloud, Bassett, Graves, Fullilove, & Brinkley-Rubinstein, 2020; Wildeman & Wang, 2017). Substandard health care within jails and prisons, unhealthy environmental factors, and the health impacts of carceral systems have been well documented (Golembeski et al., 2020b; Massoglia & Remster, 2019; Venters, 2019). A high prevalence of comorbid chronic medical and mental health conditions exists among incarcerated individuals, who are often from underserved communities (Binswanger, Redmond, Steiner, and Hicks, 2012). Mental health and substance use disorders often co-occur, with rates as high as 75 percent, accompanied by inadequate treatment (Harzke & Pruitt, 2018). People with severe mental health challenges are often stigmatized and disadvantaged, plus vulnerable to repeated arrest or incarceration, particularly absent of appropriate supports or diversion strategies (Baillargeon et al., 2009; Glied & Frank, 2009).

Incarcerated people are the only U.S. population with a constitutional guarantee to health care, including protection from serious physical and psychological harm (Dolovich, 2009). Inadequate staffing, transportation to clinics, and knowledge of

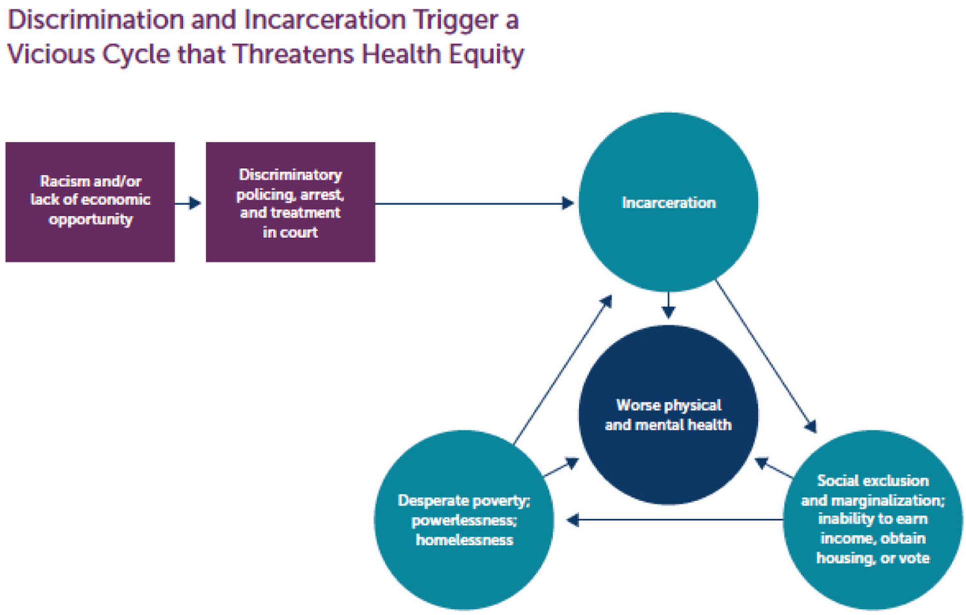



**Figure 5** Structural Racism, Economic Deprivation and the Criminal Legal System. Source: Acker et al. (2019). https://www.rwjf.org/en/library/research/2019/01/mass-incarceration-threatens-health-equity-in-america.html.

incarcerated people's location may contribute to preventable death as a systematic risk of incarceration (Venters, 2019). Moreover, Massoglia found individuals with a history of incarceration are consistently more likely to develop illnesses associated with stress (Massoglia, 2008). Understanding and addressing the health challenges of people involved in the criminal legal system is critical to achieving the triple aim of improving patient experience of care and population health while limiting costs (Binswanger, Maruschak, Mueller, Stern, & Kinner, 2019; Golembeski et al., 2020b; Mery, Majumder, Brown, & Dobrow, 2017). Ultimately, Venters and colleagues conceptualize the triple aim of correctional health as patient safety, population health, and human rights (MacDonald et al., 2013).

## Climate Change, Hyperincarceration, and Health Inequities

The intersection of anthropogenic climate change and hyperincarceration informs social and political determinants of health inequities (Dawes, 2020). Information critical of the impending carceral and climate crises upon us can be traced back to the 1970s (Alexander, 2012; Gilmore, 2007; Riccucci, 2018; Rich, 2019). Climate vulnerability, which is exacerbated in carceral contexts, is a function of exposure, sensitivity, and adaptive capacity to climate variability (Fullilove, Izenberg, Golembeski, Stitelman, & Wallace, 2020; Méndez, 2020).

Hyperincarceration can be traced back to the Black Codes and convict leasing as part of a continuum of racialized imprisonment (Bailey et al., 2017; Wildeman &

Wang, 2017). More vulnerable subpopulations within the criminal legal system, including those experiencing accelerated aging and the elderly; neurological and mental health conditions and particular comorbidities; isolation or limited mobility; and the need for certain prescription medications, especially psychotropics, are more adversely affected by extreme temperature exposure, climate-related natural disasters, and forced displacement (Martin-Latry et al., 2007; Motanya & Valera, 2016).

Most jails and prisons are not adequately adapting to climate-related changes or equipping staff for related emergencies (Holt, 2015; Skarha et al., 2020). Given the lack of systemic efforts to reduce rates of climate change and incarceration, people inside prisons and jails remain among the most vulnerable populations (Prins & Story, 2020). Climate adaptation efforts related to prisons and jails require urgent attention to meet pressing social needs; however, the primary focus should be on decarceration and improving structural determinants of health inequities.

There is a lack of original research on the health effects of incarcerated people's exposure to extreme temperatures, natural disasters, and other climate-related phenomena, yet a few analytic and descriptive reviews exist (Motanya & Valera, 2016; Prins & Story, 2020; Skarha et al., 2020). Motanya and Valera (2016) provide a descriptive review of climate change and its negative effects on incarcerated populations with a focus on climate-related natural disasters. Case studies include Hurricane Katrina and heat-related fatalities in Texas prisons lacking indoor temperature regulation (Motanya & Valera, 2016). The authors recommend solutions involving management, policy, health promotion, and environmental health frameworks, and multilevel governmental collaborations with those directly impacted by incarceration.

Skarha et al. (2020) examine the scientific evidence on the health effects of extreme temperature exposure in carceral settings. The authors call for more research, summarize existing relevant gray literature and court cases, and state how vulnerable incarcerated subpopulations are particularly susceptible to the adverse effects of extreme temperature exposure, especially heat. Diabetes, asthma, obesity, heart conditions, and mental health conditions; prescription medications affecting body temperature regulation and temperature sensitivity; accelerated aging and a growing aging population; overcrowding; and poor indoor temperature regulation, all exacerbate health and mortality risks within carceral institutions affected by extreme temperature (Holt, 2015; Motanya & Valera, 2016; Skarha et al., 2020). Mortality associated with extreme cold and heat exposure is difficult to precisely track given that many primary illnesses are affected by extreme temperature exposure (Bouchama et al., 2007; Skarha et al., 2020).

Prins and Story (2020) underscore the central role of "organized abandonment" in urban and rural communities where prisons are located and where most people, who are incarcerated, live and return.[11] In addition to citing Gilmore's extended discussion of "organized abandonment," Prins and Story (2020) posit ecogentrification and eco-apartheid as accounting for the wealthy's disproportionately larger ecological footprints displacing poorer residents who bear the brunt of climate change's health and safety threats (Gilmore, 2007). Incarceration as well as climate-induced coercive mobility, social isolation, and displacement incurs what Mindy Fullilove (2016:11) terms "root shock," which "is the traumatic stress reaction to the destruction of all or part of one's emotional ecosystem.” Furthermore, Gilmore associates organized abandonment with the antistate state in suggesting governments that purport to ideologically support state withdrawal may actually increase state expenditure to achieve their aims (2007).

Public health experts have advocated for routinizing mandatory data collection focusing on criminal legal system populations, which are largely excluded from national health surveys (Binswanger et al., 2019; Sufrin, Beal, Clarke, Jones, & Mosher, 2019; Venters, 2019). Relatedly, a lack of accurate, systematic information exists on the number of incarcerated people who die due to extreme temperature exposure or how climate change may affect criminal legal system-involved populations at present and in the future (Motanya & Valera, 2016; Prins & Story, 2020; Skarha et al., 2020). Public health expertise combined with enhanced monitoring, accountability, and transparency is necessary.

Prison and jail-attributable death, illness, and injury are receiving greater attention (Massoglia, 2008; Venters, 2019). Increasing temperature exposure intensity will inevitably lead to an increase in preventable death, illness, and injury (Bark, 1998; Bouchama et al., 2007; Mullins & White, 2019; Shindell et al., 2020). For instance, Marcia Powell was incarcerated, exposed to extreme heat, and left to die. Skarha et al. (2020, p. S42) recommend federal funding for “original epidemiological research on the health impacts of extreme temperatures in incarceration settings and to define which populations are most vulnerable.” Ultimately there is consensus on prioritizing decarceration, drug-policy reform, and alternatives to incarceration, along with decarbonization, so as to minimize injury, illness, and death.

### *Climate Disasters, Hyperincarceration, and Crisis Response Management*

Extreme weather events and climate events, with escalating frequency, severity, and unpredictability, are common ways humans experience anthropogenic climate change (Banholzer et al., 2014; Reed, Stansfield, Wehner, & Zarzycki, 2020; Stott, 2016). The Intergovernmental Panel on Climate Change IPCC (2018) predicts an increase in heat waves, rising tropical cyclone wind speed, heavy precipitation events, and increasing drought, flood, and landslide intensity in association with climate change throughout the twenty-first century (Banholzer et al., 2014). Prisons not only have large full-time permanent residential populations, but are often in lower-lying, less populated areas and prone to climate-induced catastrophies, such as floods and fires (Holt, 2015; Russell, 2014). Environmental hazard and climate threat exposure inside prisons and jails further burden often overcrowded, ill-equipped facilities lacking inadequate healthcare services (Robbins, 2008; Venters, 2019).

National Institute of Corrections (NIC) guides for preparing for and responding to prison and jail emergencies have been assessed as outdated (Motanya & Valera, 2016). The majority of emergency response checklists and documents for jails and prisons are often unavailable, deficient, or unenforceable. Facilities and staff inadequately train for disaster response and recovery, which differs from practices associated with schools, hospitals, and other institutions. Resource limitations, including a lack of generators, pumps, potable water, and food, further exacerbate existing stressors and inequities (Robbins, 2008). In addition, people in prisons and jails are vulnerable to violence, abuse, trauma, and dangerous conditions during evacuation (National Prison Project of the American Civil Liberties Union [ACLU], 2007; Robbins, 2008). Henry asserts that resource "allocation policy should account for the needs of populations, which, because of social, economic, cultural, and biological factors, are especially vulnerable to harms or injustices during emergencies" (Meltzer Henry, 2019).

Texas' Hurricane Harvey, Florida's Hurricane Michael, and Illinois and southwestern heat waves and other natural disasters have adversely impacted vulnerable populations, including those within jails and prisons. During Hurricane Sandy, Rikers Island Jail had no evacuation plan despite being located in an evacuation zone and atop a toxic waste landfill (Prins & Story, 2020). Climate-related deaths have occurred within jails and prisons as well as during transport (Hager & Santo, 2016). Wendy Newton and Nicolette Green were two mental health patient detainees that drowned in the back of a transport van during Hurricane Florence's larger and wetter aftermath due to climate change (McLaughlin & Watts, 2018; Skarha et al., 2020). The two escorting deputies, who survived, drove past a barrier amidst the storm, although there was no urgency to transport the women between facilities (McLaughlin & Watts, 2018; Reed et al., 2020).

During a 2020 summer weekend, approximately 600 wildfires burned in California, two of which are cited as the state's largest (Harshaw, 2020). The Napa Valley region was evacuated except for the two correctional facilities holding nearly 6,000 people. The California Department of Corrections removed the prisons from the mandatory evacuation listing (refer to Figure 6). When there


Figure 6 Vacaville Police Evacuation Plan with Two Prison Facilities Within the Boundaries.

is a disaster or crisis, individuals in prisons and jails often do not help decide what preparation or response efforts are best, despite the recommendations of public health experts (Venters, 2020).

People who are currently incarcerated constitute a source of firefighting labor in states such as California. This reliance on exceedingly low wage labor is estimated to save taxpayers tens of millions of dollars annually (Fuller, 2020). Firefighters, who reside in California's prisons, earn $1 an hour and withstand dangerous, deadly conditions (Fuller, 2020; Lowe, 2017). Six related deaths have occurred over a 35-year period in California.[12] Although inmate labor in California can be traced back to the 1850s, the first incarcerated people served as firefighters during World War II (Lowe, 2017). As climate change and wildfires increase, states such as California, Arizona, Nevada, Wyoming, and Georgia, may increase reliance on firefighting assistance from those incarcerated, which holds both transformative as well as exploitive potential (Feldman, 2020). Yet many county fire agencies will not hire previously incarcerated individuals with felony convictions, while probation terms may limit capacity to travel (Lowe, 2017). Recent positive developments include the 2020 California Penal Code section 1203.4b, which expunges the records of certain men and women on the front lines of wildfire containment after they serve their sentences (Moreno, 2020).

The American Civil Liberties Union (ACLU) documents the harrowing experiences of thousands of children and adults abandoned during Hurricane Katrina at the Orleans Parish Prison (OPP), which is notorious for mismanagement, neglect, and cruelty (2007). While other residents were evacuated, detainees convicted of minor offenses or not yet convicted, were deprived of food, water, ventilation, and light for days amidst the chaos, only to be transported to facilities where they were vulnerable to abuse (Robbins, 2008). The OPP lacked preparation and the emergency response was woefully inadequate. The ACLU documents the Sheriff's office hiring out “prisoners” at or below minimum wage after returning people in custody to the area despite ongoing safety assessments (National Prison Project of the American Civil Liberties Union [ACLU], 2007). In reflecting on Hurricane Katrina's aftermath, the legal scholar Ira Robbins frames prison emergency preparedness as a constitutional imperative (Robbins, 2008).

A White House Report itemizes lessons learned from Hurricane Katrina, such as improving emergency management, citizen preparedness, planning, and coordination (Robbins, 2008). The report concedes the lack of optimal interdepartmental planning, coordination, and implementation and systemic failure. Furthermore, there is no discussion of jails or prisons as part of emergency planning and management (Menzel, 2006). Weible et al. (2020) underscore how government's nondecisions become just as important as decisions that are made. Incarcerated populations are vulnerable and lacking resources prior to any climate emergencies, which further underscores the critical imperative to plan for their needs while minimizing reliance on incarceration (Meltzer Henry, 2019).

## Climate Change, Land Use, Corrections, and Health

"Toxic prisons" underscore the increasing attention to jails and prisons' proximity to federal Superfund sites and other contaminated areas (Bernd, Losftus-Farren, & Mitra, 2017). Approximately 600 federal and state prisons are located within three miles of a Superfund site on the National Priorities List, whereas over 100 prisons are within one mile of toxic sites. The U.S. Governmental Accountability Office reports that 945 toxic waste sites, equivalent to 60 percent of Superfund sites, are vulnerable to climate change and necessitate government intervention (U.S. Government Accountability Office [GAO], 2019). Climate-related extreme weather events increase hazardous waste release and exposure risks, which are especially perilous for those confined to prisons and jails (Russell, 2014).

The Environmental Protection Agency (EPA) recently added a layer to the Justice Screening and Mapping tool, which allows the public to overlay prison locations with Superfund and hazardous waste sites (Loftus-Farren, 2017). By 2011, the EPA's "prisons initiative" to improve correctional compliance with environmental regulations was shut down (Loftus-Farren, 2017). That same year, the U.S. Department of Justice and the Federal Bureau of Prisons commissioned a report on current sustainability tools, strategies, and practices within correctional facilities (Jewkes & Moran, 2015). Moving forward, greater continuity and standardizationprison emergency preparedness in general and the lack of continuity regarding planning for natural disasters.

The positive impact of prison building, particularly in economically depressed rural areas where prisons may be viewed as akin to hospitals, schools, and shopping centers, may contrast their otherwise less desirable land-use status similar to incinerators, landfills, and power plants (Eason, 2017). Negative environmental impacts of jails and prisons are not systematically documented, and most construction projects do not account for prison or jail population health outcomes (Bradshaw, 2018). Furthermore, federal environmental violations are distributed across U.S. prisons, with 241 violations in Oklahoma alone (Bernd et al., 2017; Funes, 2017). Lastly, the widespread concern of contaminated water alongside extreme heat poses serious health concerns, given the nearly 1,200 actions levied against correctional facilities under the Safe Drinking Water Act (Bernd et al., 2017).

The politics of incarceration and climate science radically influence regions endemic to infectious disease. The incidence of valley fever (Coccidioides), associated with fungus spores from desert dust, is increasing due to climate change (Coates & Fox, 2018; Gorris, Treseder, Zender, & Randerson, 2019). In 2015, a federally ordered screening found that 8 percent of people incarcerated in California prisons had the fungal disease in comparison to the state's overall infection rate of less than 1 percent (Bayles, 2016). Nearly a majority of the human population can develop sore throats and muscle pains, which may further develop into symptoms, including skin ulcers, bone lesions, and heart and lung inflammation (Center for Disease Control and Prevention [CDC], 2020). Black individuals are 14 times more likely than White individuals to suffer complications, while Filipinos are 175 times more likely (Ruddy et al., 2011). The disproportionate representation of people of color in California prisons and jails throughout hot, dry regions renders these populations further vulnerable. One recent report finds 3,500 California inmates with valley fever and 50 related deaths (Bernd et al., 2017). Climate change observations estimate that areas affected by yellow fever will double due to increased temperatures and precipitation, with a 50 percent increase of ill people by 2100 (Gorris et al., 2019).

> *Critical Environmental Justice (CEJ) views racism, heteropatriarchy, classism, nativism, ableism, ageism, speciesism (the belief that one species is superior to another), and other forms of inequality as intersecting axes of domination and control (Pellow, 2018, p. 19).*

Pellow (2019) posits the majority Brown and Black town of Fayette, Pennsylvania, which houses the state correctional institution, as a site where criminalization, climate injustice, and environmental injustice converge.[13] Incarcerated individuals here developed respiratory and heart problems, brain and liver damage, and cancer due to coal ash exposure, which contains arsenic, lead, and mercury, plus other potentially hazardous heavy metals (Bernd et al., 2017). According to a 2014 report, 81 percent of incarcerated people reported respiratory, throat, and sinus conditions, 68 percent reported stomach problems, and over 50 percent cited adverse skin conditions. Furthermore, from 2011 through 2013, 11 of 17 incarcerated adults who died had developed cancer (Bernd et al., 2017). Richard Mosley filed a related lawsuit against the prison where he was formerly incarcerated and an active Fayette Justice Health Committee healthcare campaign member (Pellow, 2019).

### *Extreme Temperature Exposure in Carceral Settings and Related Health Effects*

The deadliest weather disaster is heat, which kills up to 12,000 lives annually in the U.S. (Shindell et al., 2020). Daniel Holt proposes adaptation strategies to address how heat waves and rising temperatures, associated with climate change, affect jails and prisons (2015).[14] A Vera Institute of Justice report reveals high temperatures and poor ventilation in Louisiana segregation units as factors underlying increases in conflict, aggression, and other behaviors that result in infractions (Cloud, LaChance, Smith, & Glarza, 2019). In addition, a positive correlation exists between self-harm incidents and higher heat indexes, which were particularly pronounced during the summer. Health effects of heat exposure include increases in aggression, suicide, self-harm, poor cognitive functioning, overall poor mental health, heatstroke, heart attacks, and death (Cloud et al., 2019; Holt, 2015; Mullins & White, 2019; U.S. Global Change Research Program, 2016).

Jail and prison temperatures have been known to rise as high as 150°F when accounting for the heat index, which is a measure of how hot it actually feels when humidity is factored in with the temperature (Chammah, 2017; Chudzinski, 2018). Yet, prisons in 13 states in the warmest areas of the U.S. lack air conditioning (Jones, 2019). Although the NIC requires informing wardens and assistant commissioners when temperatures are below 68°F in all areas and above 80°F in specific areas, there are limited federal laws or state and local legislation mandating temperature control in prisons or jails (Asgarian, 2019; Skarha et al., 2020).

Socially vulnerable subpopulations increasing within prisons and jails, such as those contending with aging and comorbid medical conditions, are particularly sensitive to extreme temperatures (Chammah, 2017; Skarha et al., 2020). The prevalence of comorbid chronic conditions and the side effects of many medications for mental health conditions, high blood pressure, diabetes, and hypertension, contribute toward inhibiting the body's capacity to regulate heat and reduce body temperature as well as increasing sensitivity (Skarha et al., 2020). People with mental illness, who are grossly overrepresented in prisons and jails, are four times more likely to die of heat-related complications (Bouchama et al., 2007; Mullins & White, 2019).

Similar to Marcia Powell's death in an outside cell in Arizona, Timothy Souders of Michigan died while in solitary confinement (Erickson & Erickson, 2008; Wahab & Panichelli, 2013). Timothy Souders' autopsy attributes the cause of the 21-year-old's death to hyperthermia with dehydration during an August 2006 heatwave (Alexander, 2008). Yet, Mr. Souders' death, similar to that of Marcia Powell, was ruled an accident (Alexander, 2008). Four-points restraints, with an independent medical monitor called "torture," were used on Souders, who was incarcerated for resisting arrest and destroying police property (Bersot & Arrigo, 2011). Souders, who lived with mental illness, was disciplined for noncompliance with prison rules. Surveillance video reveals his mental and physical deterioration over the course of four days of being shackled in solitary confinement (Alexander, 2008; Bersot & Arrigo, 2011).

### *The Role of the Courts in Addressing Extreme Temperature Exposure During Incarceration*

Hoffman (Sharona, 2009) convincingly argues that amidst emergencies, vulnerable populations, including those incarcerated, are entitled to significant protection under existing legal and ethical frameworks, existing federal and state civil rights provisions, and emergency response laws. Many improvements to prison and jail conditions and healthcare services have resulted from injunctive correctional litigation (Schlanger, 2006; Skarha et al., 2020). Incarcerated individuals have successfully invoked their Eighth Amendment rights in lawsuits pertaining to cigarette smoke and asbestos exposure (Bayles, 2016). Skarha et al. (2020) identify over 1,200 Eighth Amendment cases regarding rights violations from temperature conditions within correctional contexts from 1980 to 2019, including both cold and heat exposure affecting those outdoors, in solitary confinement, and in transport.

Temperature regulation, heat or cold mitigation measures, and extreme temperatures have been consistent features of litigation and protest involving people who are detained and incarcerated. In 2010, New Hampshire state prison residents held a hunger strike to protest extreme heat and refused to eat until fans were installed (Ridgeway & Casella, 2010). In 2009, more than 400 men incarcerated during Hurricane Rita filed a federal Tort Claims Act lawsuit, which was soon dismissed, in response to negligence and substandard conditions, such as a lack of electricity, food, water, sanitation, and health care (Robbins, 2008). Relatedly, a federal judge ordered the Louisiana State Penitentiary to ensure temperatures on death row were lowered to 88°F after a heat index of 109°F was recorded (Chammah, 2017).

Although a 1977 Texas statute mandates that county jails maintain temperatures between 65 and 85°F, this state law does not apply to prisons where heat index temperatures of 150°F are recorded (Human Rights Clinic at the University of Texas School of Law, 2014). Regrettably, 70 percent of people inside state prisons are held in the majority of facilities lacking air conditioning (Clarke & Zoukis, 2018). Cost was cited as a reason to forgo retrofitting facilities with climate control. Some staff administrative areas were well equipped with air conditioning, yet Texas corrections staff have received over $500,000 in workers compensation claims associated with heat-related illnesses and injuries (Chammah, 2017). A university law clinic documented seven heat-related deaths between 2007 and 2014 (Human Rights Clinic at the University of Texas School of Law, 2014). In addition, *The Texas Tribune* reported at least ten inmate deaths, which are associated with a federal class action during a 2011 statewide heatwave, which is associated with a federal class action lawsuit. Larry McCollum died of hyperthermia due to heat-related causes in Texas Hutchins State Jail in 2011 while serving a twelve-month sentence for check fraud (Holt, 2015).

A judge issued a scathing indictment of hot prisons constituting cruel and unusual punishment and ordered the state of Texas to place medically vulnerable inmates in air conditioning (McCullough, 2018b). The State Attorney General's office spent over $7 million in legal fees before reaching a 2018 settlement regarding a prison holding 1000 inmates. Extreme temperatures are increasingly more prevalent throughout the nation and will only further adversely impact people in prisons and jails. Texas is far from the only state citing a lack of fiscal or political will as reasons to inadequately regulate temperatures within prisons. Incarcerated persons in Pennsylvania, New Jersey, and New York have filed complaints and lawsuits in response to freezing weather. For instance, inmates' families reported inadequate heating during a 2018 winter period in Texas (McCullough, 2018a). Several courts in states, such as Arizona, Mississippi, Wisconsin, and Texas, have decided related cases in favor of incarcerated people.

## The Political Economy of Climate Injustice and Hyperincarceration in the United States

Climate and criminal legal reform and advocacy efforts face challenges, such as dark money associated with correctional and extractive energy firms, which prioritize profit motives over human health and welfare (Guilbeault, 2019; Dunlap & Peter, 2013). The American Legislative Exchange Council (ALEC), a nonprofit organization of conservative state legislators and private sector representatives, has drafted model bills for Truth in Sentencing Bills and prison labor expansion

(Cooper, Heldman, Ackerman, & Farrar-Meyers, 2016). Additionally, ALEC disseminated materials downplaying the science and risks of global warming while overestimating fiscal implications (Hertel-Fernandez, 2019; Leonard, 2019). ALEC excels at forging associations with powerful conservative politicians, lobbyists, activists, and business interests in order to influence state legislatures.

One in five of ALEC model prison bills promote increased reliance on privatized goods, services, and facilities; prison labor; and a larger "criminal population" in jails and prisons (Cooper, Heldman, Ackerman, & Farrar-Meyers, 2016). ALEC's Criminal Justice Taskforce put forth bills that increase state correctional expenditures while endorsing harsher sentencing laws (Cooper, Heldman, Ackerman, & Farrar-Meyers, 2016; Leonard, 2019). Extractive energy firms constitute the most politically active and powerful ALEC constituents in averting climate change and global warming mitigation (Hertel-Fernandez, 2019). The Koch Brothers, who directly benefit from prison labor, have financed ALEC and the Criminal Justice Taskforce. Additionally, the Koch Family Foundations have donated over $145 million to groups working to discredit climate change science and policy solutions from 1997 through 2018 (Leonard, 2019).

Michaels (2020) traces climate breakdown denial to the establishment of organizations and playbooks for science and public relations against the public interest. Friel (2019) identifies the "consumptagenic system" as "an integrated network of policies, processes, governance, and modes of understanding that fuel unhealthy, environmentally destructive production and consumption," (pp. xxi–xxii). Kramer (2020) conceptualizes climate-affecting actions, including extraction, marketing and burning fossil fuels, deleting scientific data, and militarizing responses to climate associated migration, as crimes given the close association with morally blameworthy harms, public condemnation, and public sanctions. Achieving climate justice, according to Kramer (2020), requires a global nonviolent insurgency and a restructuring of the capitalist economic system, rather than criminal laws and prosecutions.

Al Gore and the Intergovernmental Panel on Climate Change jointly received the 2007 Nobel Peace Prize for developing and disseminating information on anthropogenic climate change for politicians and the public, yet political skepticism, scientific literacy deficits, and government mistrust thwart meaningful climate justice protections and progress (Riccucci, 2018; Schiermeier & Tollefson, 2007). The 2008 Second Chance Act and the 2010 Fair Sentencing Act preceded the First Step Act of 2018, which has already led to federal prison population reductions. Fifteen Many policymakers, researchers, and politicians support alternatives to incarceration, drug-policy reform, and decarceration alongside reducing punishment's collateral consequences (Golembeski et al., 2020b; Krieger, 2020; USCCR, 2019).

Story and Prins note similarities throughout climate and criminal justice reform movements, and posit the Green New Deal as an opportunity to decarcerate, provide employment and housing, and commit to climate and social justice (Prins & Story, 2020; Story & Prins, 2019). Decarbonization and decarceration interests have converged in challenging new or existing prison facilities and related adverse environmental impacts in various areas, including Kentucky, California, and Pennsylvania (Bernd et al., 2017; Eason, 2017; Story & Prins, 2019). For instance, the Prison Ecology Project, founded in 2015, began to unite concerns regarding criminal justice reform with those related to environmental sustainability and justice (Pellow, 2019).

## Conclusion

Both hyperincarceration and climate change are sobering realities of our times, with direct and indirect health and health system effects for individuals and communities. Hyperincarceration and climate crisis as determinants of health inequities constitute a Black Swan to some, despite reformers and abolitionists raising the alarm around climate and carceral crises for decades (Prins & Story, 2020; Story & Prins, 2019; Taleb, 2007). Expanded humane public policy protections are critical in addressing intersectional social-structural drivers, such as anthropogenic climate change and hyperincarceration (Bowleg, 2020; Watts et al., 2018). Major reforms, including greater transparency, accountability, and human rights protections with a focus on decarceration and decarbonization are necessary in order to mitigate current and anticipated health threats and the adverse consequences of large-scale incarceration and climate change (Story & Prins, 2020).

Collaboration between public health professionals and communities is necessary in order to advance efforts toward decarbonization, decarceration, and communication of attendant public health threats and opportunities. Improved planning, intervention, and reform efforts must include correctional institutions as well as directly impacted people and communities (Méndez, 2020; Venters, 2020). Decarbonization, decarceration, and addressing related collateral consequences of carceral and climate crises include upstream efforts that will best prevent injury, illness, and death. Local, national, and global sociopolitical movements, legal reform, and efforts to alleviate harms related to structurally and interpersonally induced violence and trauma resulting from climate and carceral injustices, are critical for a just world.

**Cynthia A. Golembeski**, is a JD/PhD student at Rutgers University, School of Law and School of Public Affairs and Administration; teaches in the New Jersey Scholarship and Transformative Education in Prisons Consortium; and is a Robert Wood Johnson Foundation Health Policy Research Scholar.

**Kimberly R. Dong**, DrPH, MS, RD, is an Assistant Professor in the Department of Public Health and Community Medicine at Tufts University School of Medicine.

**Ans Irfan**, is a multidisciplinary climate change and health researcher, faculty, and director of Climate & Health Equity Practice Fellowship at the Milken Institute School of Public Health, George Washington University, also serving as a fellow with the Robert Wood Johnson Foundation Health Policy Research Scholars Program.

## Notes

Conflicts of interest: None declared.

**Corresponding author**: Cynthia A. Golembeski, cag348@rutgers.edu

1. Jails are typically short-term holding facilities under local jurisdiction for the newly arrested, people awaiting trial or sentencing, and individuals serving short sentences. State or federal prisons are institutional facilities where individuals who are convicted serve longer sentences.
2. Venters writes that "jail-attributable" deaths [or injuries] are caused by actions or events taken inside correctionalfacilities. Venters (2019) suggests that jail-attributable deaths represent from 25 to 33 percent of overall jail deaths, and the Department Of Justice or the Centers for Disease Control and Prevention should facilitate mandatory reporting of rates of these types of deaths across jail settings.
3. Sufrin (2017) explains how "mass incarceration" is a widely used term to reference the vast rise in how many people have been incarcerated over the past three decades. Sufrin prioritizes Wacquant's term, "hyperincarceration," to clarify that the surge in incarceration has not involved the masses but rather disproportionately targeted poor, black men (Wacquant, 2010).
4. A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use (Intergovernmental Panel on Climate Change [IPCC], 2012).
5. $CO_2$ is a naturally occurring gas fixed by photosynthesis into organic matter. A byproduct of fossil fuel combustion and biomass burning, it is also emitted from land-use changes and other industrial processes. It is the principal anthropogenic greenhouse gas that affects the Earth's radiative balance. It is the reference gas against which other greenhouse gases are measured, thus having a Global Warming Potential of 1 (IPCC, 2012).
6. Cumulative $CO_2$ emissions represent the total sum of $CO_2$ emissions produced from fossil fuels and cement since 1751 and is measured in metric tons.
7. Conservatives and liberals have both debated the terminology that best frames climate change. Frank Lutz encouraged the Bush Administration to convince voters of the scientific community's lack of consensus regarding global warming, whereas George Lakoff suggests "climate crisis" is the most apt turn of phrase (Gore, 2006; Lakoff, 2010; Raz, 2010).
8. Greenhouse gases are gaseous constituents of the atmosphere, both natural and anthropogenic, which absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, by the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapor ($H_2O$), carbon dioxide ($CO_2$), nitrous oxide ($N_2O$), methane ($CH_4$), and ozone ($O_3$) are the primary greenhouse gases in the Earth's atmosphere. Moreover, there are a number of entirely human-made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances, dealt with under the Montreal Protocol. Besides $CO_2$, $N_2O$, and $CH_4$, the Kyoto Protocol deals with the greenhouse gases sulfur hexafluoride (SF6), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs) (IPCC, 2012).
9. Women and men involved in the criminal legal system include adults serving sentences in prisons and jails, awaiting trial or sentencing, and individuals under community supervision. We try to use person-first and nonstigmatizing or pejorative language (Tran et al., 2018).
10. Collateral consequences are "formal legal and regulatory sanctions that the convicted bear beyond the sentence imposed by a criminal court; and the informal impacts of criminal [legal system] contact on families, communities, and democracy" (Kirk & Wakefield, 2018).
11. Organized abandonment is a concept that has been utilized by Peter Drucker, David Harvey, and Ruth Wilson Gilmore. Prins and Story (2020) cite Gilmore (2007) in suggesting that organized abandonment of state responsibilities to citizens and residents to provide basic levels of safety and security "is often accompanied by expanded carceral infrastructure rather than investment, regeneration, and cultivation."
12. California's incarcerated men and women typically earn between 8 and 95 cents an hour in making office furniture for state employees, state license plates, or prison uniforms. A California conservation camp housing women pays a maximum of $2.56 a day in camp and $1 an hour when fighting fires (Lowe, 2017).

13. Pellow describes mass incarceration as "an extractive activity that could be reframed as an environmental injustice. [sic] After all, family members, friends, neighbors, co-workers, and colleagues are literally siphoned off from their homes and social networks every day; they are critical *resources* for maintaining the functioning of our communities. Why not think of that as a form of environmental injustice" (Pellow, 2018, p. 98).
14. Holt (2015) introduces adaptation options: Reduction of the incarcerated population; Reduction of the prisoner and correctional staff's heat stress susceptibility; phasing out of most vulnerable facilities; retrofitting adaptable facilities by maximizing passive cooling; building new, sustainable, adapted, and resilient facilities; requiring adequate cooling in private facilities; along with improving collaboration and cooperation.
15. Republican Senator John Cornyn of Texas and Democratic Senator Sheldon Whitehouse of Rhode Island introduced legislation enabling eligible prisoners to receive sentence reductions as part of curbing prison population growth in 2015.

## References

Acker, Julia, Paula Braveman, Elaine Arkin, Laura Leviton, jim Parsons, and George Hobor. 2019. *Mass Incarceration Threatens Health Equity in America. Executive Summary*., Princeton, NJ: Robert Wood Johnson Foundation. https://www.rwjf.org/content/dam/farm/reports/issue_briefs/2018/rwjf450812. Accessed December 04, 2020.

Alexander, Elizabeth. 2008. "Prison Health Care, Political Choice, and the Accidental Death Penalty." *University of Pennsylvania Journal of Constitutional Law* 11: 1–22.

Alexander, Michelle. 2012. *The New Jim Crow: Mass Incarceration in the Age of Colorblindness*, New York: New Press.

American Medical Association. 2019. *Global Climate Change and Human Health Policy (H-135.938)* [Online]. https://policysearch.ama-assn.org/policyfinder/detail/climate%20change?uri=%2FAMADoc%2FHOD.xml-0-309.xml. Accessed December 04, 2020.

American Public Health Association. 2015. *Public Health Opportunities to Address the Health Effects of Climate Change (Policy#20157)* [Online]. https://www.apha.org/policies-and-advocacy/public-health-policy-statements/policy-database/2015/12/03/15/34/public-health-opportunities-to-address-the-health-effects-of-climate-change. Accessed December 21, 2020.

Asgarian, Roxanna. 2019. "Why People Are Freezing in America's Prisons." Vox, December 13. https://www.vox.com/identities/2019/12/13/21012730/cold-prison-incarcerated-winter. Accessed December 04, 2020.

Bailey, Zinzi D., Nancy Krieger, Madina Agénor, Jasmine Graves, Natalia Linos, and Mary T. Bassett. 2017. "Structural Racism and Health Inequities in the USA: Evidence and Interventions." *The Lancet* 389: 1453–63.

Baillargeon, Jacques, A. Binswanger Ingrid, V. Penn Joseph, A. Williams Brie, and J. Murray Owen. 2009. "Psychiatric Disorders and Repeat Incarcerations: The Revolving Prison Door." *American Journal of Psychiatry* 166 (1): 103–109. https://doi.org/10.1176/appi.ajp.2008.08030416

Banholzer, Sandra, James Kossin, and Simon Donner. 2014. "The Impact of Climate Change on Natural Disasters." In *Reducing disaster: Early Warning Systems for Climate Change*, eds. Ashbindu Singh, and Zinta Zommers. Dordrecht: Springer, 21–49.

Bark, Nigel. 1998. "Deaths of Psychiatric Patients During Heat Waves." *Psychiatric Services* 49 (8): 1088–90.

Barnert, Elizabeth, Cyrus Ahalt, and Brie Williams. 2020. "Prisons: Amplifiers of the COVID-19 Pandemic Hiding in Plain Sight." *American Journal of Public Health* 110 (7): 964–66.

Bayles, Cara. 2016. "Behind Bars on Polluted Land: Do Americans Suffer from Environmental Discrimination?" *The Atlantic* May 24. https://www.theatlantic.com/health/archive/2016/05/behind-bars-on-polluted-land/484202/. Accessed September 04, 2020.

Bernd, Candace, Zoe Losftus-Farren, and Maureen Nandini Mitra. 2017. "America's Toxic Prisons: The Environmental Injustices of Mass Incarceration." *Earth Island Journal.* https://earthisland.org/journal/americas-toxic-prisons/. Accessed September 04, 2020.

Bersot, Heather Y., and Bruce A. Arrigo. 2011. "The Ethics of Mechanical Restraints in Prisons and Jails: A Preliminary Inquiry from Psychological Jurisprudence." *Journal of Forensic Psychology Practice* 11 (2-3): 232–64.

Binswanger, Ingrid A., Nicole Redmond, John Steiner, and Le. Roi Hicks. 2012. "Health Disparities and the Criminal Justice System: An Agenda for Further Research and Action." *Journal of Urban Health* 89 (1): 98–107.

Binswanger, Ingrid A., Laura M. Maruschak, Shane R. Mueller, Marc F. Stern, and Stuart A. Kinner. 2019. "Principles to Guide National Data Collection on the Health of Persons in the Criminal Justice System." *Public Health Reports* 134 (1_suppl): 34S–45S.

Bouchama, Abderrezak, Mohammed Dehbi, Gamal Mohamed, Franziska Matthies, Mohamed Shoukri, and Bettina Menne. 2007. "Prognostic Factors in Heat Wave–Related Deaths: A Meta-Analysis." *Archives of Internal Medicine* 167 (20): 2170–76.

Bowleg, Lisa. 2020. "Reframing Mass Incarceration as a Social-Structural Driver of Health Inequity." *American Journal of Public Health* 110 (S1): S11–12.

Bowen, Elizabeth A., and Murshid Nadine Shaanta. 2016. "Trauma-Informed Social Policy: A Conceptual Framework for Policy Analysis and Advocacy." *American Journal of Public Health* 106 (2): 223–229. https://doi.org/10.2105/ajph.2015.302970

Bradshaw, Elizabeth A. 2018. "Tombstone Towns and Toxic Prisons: Prison Ecology and the Necessity of an Anti-Prison Environmental Movement." *Critical Criminology* 26 (3): 407–22.

Carson, E. Ann. 2020. "Prisoners in 2018." U.S. Department of Justice: Office of Justice Programs, Bureau of Justice Statistics, NCJ 253516. https://www.bjs.gov/content/pub/pdf/p18.pdf. Accessed September 04, 2020.

Center for Disease Control and Prevention (CDC). 2020. *Valley fever (coccidioidomycosis)* [Online]. https://www.cdc.gov/fungal/diseases/coccidioidomycosis/index.html. Accessed September 04, 2020.

Chammah, Maurice. 2017. "Cooking Them to Death: The Lethal Toll of Hot Prisons." The Marshall Project. October 11. https://www.themarshallproject.org/2017/10/11/cooking-them-to-death-the-lethal-toll-of-hot-prisons. Accessed September 04, 2020.

Chesney-Lind, Meda, and Marc Mauer, eds. 2003. *Invisible Punishment: The Collateral Consequences of Mass Imprisonment*, New York: The New Press.

Chudzinski, Kellie. 2018. "Why Temperatures in Jails and Prisons Matter." Vera Institute of Justice Think Justice Blog. August 10. https://www.vera.org/blog/why-temperatures-in-prisons-and-jails-matter. Accessed September 04, 2020.

Clarke, Matthew, and Christopher Zoukis. 2018. "Litigation Heats Up Over Extreme Temperatures in Prisons, Jails." Prison Legal News. June 29. https://www.prisonlegalnews.org/news/2018/jun/29/litigation-heats-over-extreme-temperatures-prisons-jails/. Accessed September 04, 2020.

Cloud, David, Jessi LaChance, Lionel Smith, and Lauren Glarza. 2019. *The Safe Alternatives to Segregation Initiative: Findings and Recommendations for the Louisiana Department of Public Safety and Corrections, and Progress Toward Implementation*. Washington, DC: Vera Institute of Justice. https://www.vera.org/downloads/publications/safe-alternatives-segregation-initiative-findings-recommendations-ldps.pdf. Accessed September 04, 2020.

Cloud, David H., Mary T. Bassett, Jasmine Graves, Robert E. Fullilove, and Lauren Brinkley-Rubinstein. 2020. "Documenting and Addressing the Health Impacts of Carceral Systems." *American Journal of Public Health* 110 (S1): S5.

Coates, Sarah J., and Lindy P. Fox. 2018. "Disseminated Coccidioidomycosis as a Harbinger of Climate Change." *JAAD Case Reports* 4 (5): 424–425.

Cole, Luke W., and Sheila R. Foster. 2001. *From the Ground Up: Environmental Racism and the Rise of the Environmental Justice Movement*, New York: New York University Press.

Conway, Erik. 2008. *What's in a Name? Global Warming vs. Climate Change*, Washington, DC: National Aeronautics and Space Administration (NASA), Internet Resource, News Topics: Looking at Earth; Feature. December 05. https://www.nasa.gov/topics/earth/features/climate_by_any_other_name.html. Accessed September 04, 2020.

Cook, John, Naomi Oreskes, Peter T. Doran, William R.L. Anderegg, Bart Verheggen, Ed W. Maibach, J Stuart Lewandowsky S. et al. 2016. "Consensus on Consensus: A Synthesis of Consensus Estimates on Human-Caused Global Warming." *Environmental Research Letters* 11 (4): 1–7.

Cooper, Rebecca, Caroline Heldman, Alissa R. Ackerman, and Victoria A. Farrar-Meyers. 2016. "Hidden Corporate Profits in the US Prison System: The Unorthodox Policy-Making of the American Legislative Exchange Council." *Contemporary Justice Review* 19 (3): 380–400.

Cooper, Heldman Caroline Rebecca, R. Ackerman Alissa, and A. Farrar-Meyers Victoria. 2016. "Hidden corporate profits in the U.S. prison system: the unorthodox policy-making of the American Legislative Exchange Council." *Contemporary Justice Review* 19 (3): 380–400. https://doi.org/10.1080/10282580.2016.1185949

Davis, Brigette. 2020. "Discrimination: A Social Determinant of Health Inequities." *Health Affairs Blog*. February 25. https://www.healthaffairs.org/do/10.1377/hblog20200220.518458/full/. Accessed September 04, 2020.

Dawes, Daniel. 2020. *The political determinants of health*, Baltimore: Johns Hopkins University Press.

Dolovich, Sharon. 2009. "Cruelty, Prison Conditions, and the Eighth Amendment." *New York University Law Review* 84 (4): 881–979.

Dunlap, Riley, and Jacques Peter. 2013. "Climate Change Denial Books and Conservative Think Tanks." *American Behavioral Scientist* 57 (6): 699–731.

Eason, John M. 2017. *Big House on the Prairie: Rise of the Rural Ghetto and Prison Proliferation*, Chicago, IL: University of Chicago Press.

Erickson, Patricia, and Erickson Steven. 2008. *Crime, Punishment, and Mental Illness: Law and the Behavioral Sciences in Conflict*, New Brunswick: Rutgers University Press. https://www.rutgersuniversitypress.org/crime-punishment-and-mental-illness/9780813543383

Feldman, Lindsey Raisa. 2020. "Anti-heroes, wildfire, and the complex visibility of prison labor." *Crime, Media, Culture: An International Journal* 16 (2): 221–238. https://doi.org/10.1177/1741659019865309

Flagg, Anna, and Neff, Joseph. 2020. Why Jails Are So Important in the Fight Against Coronavirus. *The New York Times* (March 31). https://www.nytimes.com/2020/03/31/upshot/coronavirus-jails-prisons.html. Accessed September 04, 2020.

Friel, Sharon. 2019. *Climate Change and the People's Health*, Oxford: Oxford University Press.

Fuller, Thomas. 2020. Coronavirus Limits California's Efforts to Fight Fires with Prison Labor. *The New York Times*. August 22. https://nyti.ms/3glT9wb. Accessed September 04, 2020.

Fullilove, Mindy Thompson. 1993. "Perceptions and Misperceptions of Race and Drug Use." *Journal of the American Medical Association* 269 (8): 1034.

———. 2016. *Root Shock: How Tearing Up City Neighborhoods Hurts America, and What We Can Do About It*, New York: New Village Press.

Fullilove, Mindy Thompson, Jacob M. Izenberg, Cynthia Golembeski, Martha Stitelman, and Rodrick Wallace. 2020. "Main Streets and Disaster: A Study of Regional Collective Efficacy." *City* 24: 1–12.

Funes, Yessenia. 2017. "How Prisons Are Affected by Climate Change." Colorlines. June 02. https://www.colorlines.com/articles/read-how-prisons-are-affected-climate-change. Accessed September 04, 2020.

Gilmore, Ruth Wilson. 2007. *Golden Gulag: Prisons, Surplus, Crisis, and Opposition in Globalizing California*, Berkeley, CA: University of California Press.

Glied, Sherry A., and G. Frank Richard. 2009. "Better But Not Best: Recent Trends In The Well-Being Of The Mentally Ill." *Health Affairs* 28 (3): 637–648. https://doi.org/10.1377/hlthaff.28.3.637

Golembeski, Cynthia, and Robert Fullilove. 2008. "Criminal (In)Justice In the City and Its Associated Health Consequences." *American Journal of Public Health* 98 (9 Suppl): S185–90.

Golembeski, Cynthia A., Ans Irfan, and Kimberly R. Dong. 2020a. "Food Insecurity and Collateral Consequences of Punishment Amidst the COVID-19 Pandemic." *World Medical & Health Policy* 12 (4): 357–73.

Golembeski, Cynthia A., Carolyn B. Sufrin, Brie Williams, Precious S. Bedell, Sherry A. Glied, Ingrid A. Binswanger, Donna Hylton, Tyler N. A. Winkelman, and Jaimie P. Meyer. 2020b. "Improving

Health Equity for Women Involved in the Criminal Legal System." *Women's Health Issues* 30 (5): 313–19.

Gore, Al. 2006. *An Inconvenient Truth: The Planetary Emergency of Global Warming and What We Can Do About It*, New York: Rodale Press.

Gorris, Morgan E., Kathleen K. Treseder, Charles S. Zender, and James T. Randerson. 2019. "Expansion of Coccidioidomycosis Endemic Regions in the United States in Response to Climate Change." *GeoHealth* 3 (10): 308–27.

Gottschalk, Marie. 2015. *Caught: The Prison State and the Lockdown of American Politics*, Princeton, NJ: Princeton University Press.

Guilbeault, Douglas. 2019. *Anti-Climate Science: Computational Propaganda in the United States: A Review of Disinformation Campaigns and Collective Intelligence Interventions*, Palo Alto: Digital Intelligence Futures Lab at the Institute for the Future. https://www.iftf.org/fileadmin/user_upload/downloads/ourwork/IFTF_Anti-Climate_comp.prop_W_05.07.19.pdf. Accessed September 04, 2020.

Hager, Eli, and Santo, Alysia. 2016. "Inside the Deadly World of Private Prisoner Transport." The Marshall Project. https://www.themarshallproject.org/2016/07/06/inside-the-deadly-world-of-private-prisoner-transport. Accessed September 04, 2020.

Harzke, Amy J., and Sandi L. Pruitt. 2018. "Chronic Medical Conditions in Criminal Justice Involved Populations." *Journal of Health and Human Services Administration* 41 (3): 306–47.

Harshaw, Pendarvis. 2020. "Let's Talk About Wildfires and Prisons." *KQED Commentary*. https://www.kqed.org/arts/13885195/lets-talk-about-wildfires-and-prisons

Herrnstadt, Evan, Anthony Heyes, Erich Muehlegger, and Soodeh Saberian. 2020. "Air Pollution and Criminal Activity: Microgeographic Evidence from Chicago." *American Economic Journal: Applied Economics* https://www.aeaweb.org/articles?id=10.1257/app.20190091%26%26from=f. Accessed September 04, 2020.

Hertel-Fernandez, Alex. 2019. *State Capture: How Conservative Activists, Big Businesses, and Wealthy Donors Reshaped the American States and the Nation*, New York: Oxford University Press.

Hinton, Elizabeth K. 2016. *From the War on Poverty to the War on Crime: The Making of Mass Incarceration in America*, Cambridge: Harvard University Press.

Holt, Daniel W. E. 2015. *Heat in U.S. Prisons and Jails: Corrections and the Challenge of Climate Change*, New York: Columbia Law School Sabin Center for Climate Change Law. https://web.law.columbia.edu/sites/default/files/microsites/climate-change/holt__heat_in_us_prisons_and_jails.pdf. Accessed September 04, 2020.

Hoffman, Sharona. 2009. "Preparing for Disaster: Protecting the Most Vulnerable in Emergencies." *U.C. Davis Law Review* 42: 1491–1547. https://lawreview.law.ucdavis.edu/issues/42/5/articles/42-5_Hoffman.pdf

Human Rights Clinic at the University of Texas School of Law. 2014. *Deadly Heat in Texas Prisons*, Austin: Human Rights Clinic at the University of Texas School of Law. https://law.utexas.edu/wp-content/uploads/sites/11/2015/05/2014-HRC-USA-DeadlyHeat-Report.pdf. Accessed September 04, 2020.

Intergovernmental Panel on Climate Change (IPCC). 2012. "Glossary of Terms." In *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, eds. C. B. Field, V. Barros, T. F. Stocker, D. Qin, D. J. Dokken, K. L. Ebi, M. D. Mastrandrea, K. J. Mach, G. -K. Plattner, S. K. Allen, M. Tignor, and P. M. Midgley. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge: Cambridge University Press, 555–64.

Intergovernmental Panel on Climate Change (IPCC). 2018. "Summary for Policymakers." In *Global Warming Of 1.5°C. An IPCC Special Report On The Impacts Of Global Warming of 1.5°C Above Pre-Industrial Levels And Related Global Greenhouse Gas Emission Pathways, In The Context Of Strengthening The Global Response To The Threat Of Climate Change, Sustainable Development, And Efforts To Eradicate Poverty*, eds. V. Masson-Delmotte, P. Zhai, H. -O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield. Geneva: World Meteorological Organization, Geneva, Switzerland. 32 pp.

Jewkes, Yvonne, and Doran Moran. 2015. "The Paradox of the 'Green' Prison: Sustaining the Environment or Sustaining the Penal Complex?" *Theoretical Criminology* 19 (4): 451–69.

Jones, Alexi. 2019. "Cruel and Unusual Punishment: When States Don't Provide Air Conditioning in Prison." *Prison Policy Initiative* July 18. https://www.prisonpolicy.org/blog/2019/06/18/air-conditioning/. Accessed September 04, 2020.

Kamarck, Elaine. 2019. *The Challenging Politics of Climate Change*, September 10. Washington, DC: Brookings Institute. https://www.brookings.edu/research/the-challenging-politics-of-climate-change/. Accessed September 04, 2020.

Kirk, David, and Sara Wakefield. 2018. "Collateral Consequences of Punishment: A Critical Review and Path Forward." *Annual Review of Criminology* 1 (1): 171–94.

Kramer, Ronald. 2020. *Carbon Criminals, Climate Crimes*, New Brunswick: Rutgers University Press.

Krieger, Nancy. 2020. "ENOUGH: COVID-19, Structural Racism, Police Brutality, Plutocracy, Climate Change—and Time for Health Justice, Democratic Governance, and an Equitable, Sustainable Future." *American Journal of Public Health* 110: e1–4. https://doi.org/10.2105/AJPH.2020.305886. Accessed September 04, 2020.

Lakoff, George. 2010. "Why it Matters How We Frame the Environment." *Environmental Communication* 4 (1): 70–81.

Leonard, Christopher. 2019. *Kochland: The Secret History of Koch Industries and Corporate Power in America*, New York: Simon and Schuster.

Loftus-Farren, Zoe. 2017. "EPA Adds Prison Locations to Its Environmental Justice Mapping Tool." *Earth Island Journal.* September 21. https://www.ecowatch.com/prison-locations-environmental-justice-2488013644.html. Accessed September 04, 2020.

Lowe, Jaime. 2017. "The Incarcerated Women Who Fight California's Wildfires." *The New York Times*, August 31. https://nyti.ms/2wUIW7B. Accessed September 04, 2020.

Maricopa County Office of the Medical Examiner, *(2009). Report of Autopsy: Marcia Joann Powell. (09-02884). Phoenix, Arizona*.

Martin-Latry, Karin, Marie-Pierre Goumy, Philippe Latry, Claude Gabinski, Bernard Bégaud, Isabelle Faure, and Hélène Verdoux. 2007. "Psychotropic Drugs Use and Risk of Heat-Related Hospitalization." *European Psychiatry* 22 (6): 335–38.

Massoglia, Michael. 2008. "Incarceration as Exposure: The Prison, Infectious Disease, and other Stress-Related Illnesses." *Journal of Health and Social Behavior* 49 (1): 56–71.

Massoglia, Michael, and William Alex Pridemore. 2015. "Incarceration and Health." *Annual Review of Sociology* 41: 291–310.

Massoglia, Michael, and Brianna Remster. 2019. "Linkages Between Incarceration and Health." *Public Health Reports* 134 (1_supp): 8S–14S.

Mayo Clinic. 2020. *Mayo Clinic Patient Care and Health Information. Diseases and Conditions: Heat Exhaustion* [Online]. https://www.mayoclinic.org/diseases-conditions/heat-exhaustion/symptoms-causes/syc-20373250. Accessed September 04, 2020.

MacDonald, Ross, Parsons Amanda, and D. Venters Homer. 2013. "The Triple Aims of Correctional Health: Patient Safety, Population Health, and Human Rights." *Journal of Health Care for the Poor and Underserved* 24 (3): 1226–1234. https://doi.org/10.1353/hpu.2013.0142

McCullough, Jolie. 2018a. "Relatives Report Inadequate Heating at More Than 30 Texas Prisons." The Texas Tribune. January 03. https://www.texastribune.org/2018/01/03/relatives-report-inadequate-heating-more-30-texas-prisons/. Accessed September 04, 2020.

———. 2018b. "After $7 Million Legal Flight Over Air Conditioning, Texas Prison System Touts New Heat Safety Policies." The Texas Tribune. July 26. https://www.texastribune.org/2018/07/26/texas-prison-heat-air-conditioning-costs/. Accessed September 04, 2020.

McLaughlin, Eliott, and Amanda Watts. 2018. "Two Women Drown in Back of Van Swept Away by Florence Flooding." *CNN* September 20. https://www.cnn.com/2018/09/19/us/south-carolina-inmates-drown-flood-florence/index.html. Accessed September 04, 2020.

Meltzer Henry, Leslie. 2019. An Overview of Public Health Ethics in Emergency Preparedness and Response. Anna Mastroianni Jeffrey Kahn & Nancy Kass The Oxford Handbook of Public Health Ethics, Oxford: Oxford University Press. https://doi.org/10.1093/oxfordhb/9780190245191.013.66

Méndez, Michael A. 2020. *Climate Change From the Streets: How Conflict and Collaboration Strengthen the Environmental Justice Movement*, New Haven: Yale University Press.

Menzel, Donald C. 2006. "The Katrina Aftermath: A Failure of Federalism or Leadership?" *Public Administration Review* 66 (6): 808–12.

Mery, Gustavo, Shilpi Majumder, Adalsteinn Brown, and Mark J. Dobrow. 2017. "What Do We Mean When We Talk about the Triple Aim? A Systematic Review of Evolving Definitions and Adaptations of the Framework at the Health System Level." *Health Policy* 121 (6): 629–36.

Michaels, David. 2020. *The Triumph of Doubt: Dark Money and the Science of Deception*, Oxford: Oxford University Press.

Mora, Camilo, Bénédicte Dousset, Iain R. Caldwell, Farrah E. Powell, Rollan C. Geronimo, Coral r. Bielecki, Chelsie W. W. Counsell et al. 2017. "Letter Published Online: Global Risk of Deadly Heat." *Nature*, June 19. https://www.sciencedaily.com/releases/2017/06/170619120507.htm. Accessed September 04, 2020.

Moreno, J. Edward. 2020. "Newsom Signs Legislation Allowing Pathway for Inmate Firefighters to Become Professional After Release." The Hill. September 12. https://thehill.com/homenews/state-watch/516157-newsom-signs-legislation-allowing-pathway-for-inmate-firefighters-to. Accessed September 04, 2020.

Motanya, Njideka C., and Pamela Valera. 2016. "Climate Change and Its Impact on the Incarcerated Population: A Descriptive Review." *Social Work in Public Health* 31 (5): 348–57.

Muhammad, Kabril G. 2010. *The Condemnation of Blackness: Race, Crime, and the Making of Modern Urban America*, Cambridge: Harvard University Press.

Mullins, Jamie T., and Corey White. 2019. "Temperature and Mental Health: Evidence from the Spectrum of Mental Health Outcomes." *Journal of Health Economics* 68: 102240. https://doi.org/10.1016/j.jhealeco.2019.102240. Accessed September 04, 2020.

National Aeronautics and Space Administration (NASA). *The Effects of Climate Change." Climate Change: Vital Signs of the Planet* [Online]. https://climate.nasa.gov/effects. Accessed September 20, 2020.

National Prison Project of the American Civil Liberties Union (ACLU). 2007. "Abandoned and Abused: Prisoners in the Wake of Hurricane Katrina." *Race and Class* 49 (1): 81–92. https://doi.org/10.1177/0306396807080069

Intergovernmental Panel on Climate Change. 2014. "Adaptation needs and options." In *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, and Cambridge: Cambridge University Press, 833–868.

Nowotny, Kathryn, Zinzi Bailey, Marisa Omori, and Lauren Brinkley-Rubinstein. 2020. "COVID-19 Exposes Need for Progressive Criminal Justice Reform." *American Journal of Public Health* 110 (7): 967–68.

Park, R. Jisung, Joshua Goodman, and A. Patrick Behrer. 2020. "Learning is Inhibited by Heat Exposure, Both Internationally and Within the United States." *Nature Human Behaviour* 1–9. https://doi.org/10.1038/s41562-020-00959-9

Patterson, E. J. 2013. "The Dose–Response of Time Served in Prison on Mortality: New York State, 1989–2003." *American Journal of Public Health* 103 (3): 523–28.

Pellow, David N. 2019. "Struggles for Environmental Justice in US Prisons and Jails." *Antipode*, September. https://doi.org/10.1111/anti.12569. Accessed September 04, 2020.

——— 2018. *What Is Critical Environmental Justice?*, Cambridge: Polity.

Prins, Seth J., and Brett Story. 2020. "Connecting the Dots Between Mass Incarceration, Health Equity, and Climate Change." *American Journal of Public Health* 110: S35–S36. https://doi.org/10.2105/AJPH.2019.305470. Accessed September 04, 2020.

Raz, Guy [host] All Things Considered Radio Broadcast Episode. 2010. "Linguist Weighs in on Framing Climate Change." February 21. https://www.npr.org/templates/story/story.php?storyId=123950399. Accessed September 04, 2020.

Reed, Kevin A., A. M. Stansfield, M. F. Wehner, and C. M. Zarzycki. 2020. "Forecasted Attribution of the Human Influence on Hurricane Florence." *Science Advances* 6 (1): eaaw9253. https://doi.org/10.1126/sciadv.aaw9253

Riccucci, Norma. 2018. *Policy Drift: Shared Powers and the Making of US Law and Policy*, New York: NYU Press.

Rich, Nathaniel. 2019. *Losing Earth: A Recent History*, New York: Farrar, Straus and Giroux.

Ridgeway, James, and Jean Casella. 2010. "When Summer is Torture." *Mother Jones*. July 27. https://www.motherjones.com/crime-justice/2010/07/heat-wave-kills-prison-inmates/. Accessed September 04, 2020.

Ritchie, Hannah, and Max Roser. 2017. "$CO_2$ and Greenhouse Gas Emissions." *Our World in Data* https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions#citation. Accessed September 04, 2020.

Robbins, Ira P. 2008. "Lessons from Hurricane Katrina: Prison Emergency Preparedness as a Constitutional Imperative." *University of Michigan Journal of Law Reform* 42: 1–70.

Rosenberg, Alana, Allison K. Groves, and Kim M. Blankenship. 2017. "Comparing Black and White Drug Offenders: Implications for Racial Disparities in Criminal Justice and Reentry Policy and Programming." *Journal of Drug Issues* 47 (1): 132–42.

Ruddy, Barbara E., Anita P. Mayer, Marcia G. Ko, Helene R. Labonte, Jill A. Borovansky, Erika S. Boroff, and Janis E. Blair. 2011. "Coccidioidomycosis in African Americans." *Mayo Clinic Proceedings* Jan 86 (1): 63–9. https://doi.org/10.4065/mcp.2010.0423

Russell, Emily. 2014. "Superfund and Climate Change: Lessons from Hurricane Sandy." *Natural Resources & Environment* 28 (3): 3–7.

Schiermeier, Quirin, and Jeff Tollefson. 2007. "Climate Change: A Nobel Cause." *Nature* 449 (7164): 766–68.

Schlanger, Margo. 2006. "Civil Rights Injunctions over Time: A Case Study of Jail and Prison Court Orders." *NYU Law Review* 81 (2): 550–630.

Shindell, Drew, Yuqiang Zhang, Melissa Scott, Muye Ru, Krista Stark, and Kristie L. Ebi. 2020. "The Effects of Heat Exposure on Human Mortality Throughout the United States." *Geohealth* 4 (4): e2019GH000234.

Skarha, Julianna, Meghan Peterson, Josiah D. Rich, and David Dosa. 2020. "An Overlooked Crisis: Extreme Temperature Exposures in Incarceration Settings." *American Journal of Public Health* 110: S41–S42. https://doi.org/10.2105/AJPH.2019.305453

Story, Brett, and Prins Seth. 2020. "A green new deal for incarceration." Jacobin, https://jacobinmag.com/2019/08/green-new-deal-decarceration-environment-prison-incarceration

Story, Brett, and Seth J. Prins. 2019. "A Green New Deal for Incarceration." *Jacobin*, August 28. https://www.jacobinmag.com/2019/08/green-new-deal-decarceration-environment-prison-incarceration. Accessed September 04, 2020.

Stott, Peter. 2016. "How Climate Change Affects Extreme Weather Events." *Science* 352 (6293): 1517–18.

Sufrin, Carolyn. 2017. *Jailcare: Finding The Safety Net for Women Behind Bars*, Berkeley, CA: University of California Press.

Sufrin, Carolyn, Lauren Beal, Jennifer Clarke, Rachel Jones, and William D. Mosher. 2019. "Pregnancy Outcomes in US Prisons, 2016–2017." *American Journal of Public Health* 109 (5): 799–805.

Sugie, Naomi F. 2012. "Punishment and Welfare: Paternal Incarceration and Families' Receipt of Public Assistance." *Social Forces* 90 (4): 1403–27.

Sze, Julie. 2020. *Environmental Justice in a Moment of Danger*, Berkeley, CA: University of California Press.

Taleb, Nassim Nicholas. 2007. *The Black Swan: The Impact Of The Highly Improbable*, New York: Random House.

Thomas, Kimberley, R. Dean Hardy, Heather Lazrus, Michael Méndez, Ben Orlove, Isabel Rivera-Collazo, J. Timmons Roberts, Marcy Rockman, Benjamin P. Warner, and Robert Winthrop. 2019.

"Explaining Differential Vulnerability to Climate Change: A Social Science Review." *Wiley Interdisciplinary Reviews: Climate Change* 10 (2): e565.

Thorpe, Roland, J., Keith C. Norris, Bettina M. Beech, and Marino A. Bruce. 2019. "Racism Across the Life Course." In *Racism: Science and Tools for the Public Health Professional*, eds. C. L. Ford, D. M. Griffith, M. A. Bruce, and K. L. Gilbert. Washington, DC: American Public Health Association Press.

Tran, Nguyen Toan, Stéphanie Baggio, Angela Dawson, Éamonn O'Moore, Brie Williams, Precious Bedell, Olivier Simon, Willem Scholten, Laurent Getaz, and Hans Wolff. 2018. "Words Matter: A Call for Humanizing and Respectful Language to Describe People Who Experience Incarceration." *BMC International Health and Human Rights* 18 (1): 41. https://doi.org/10.1186/s12914-018-0180-4. Accessed September 04, 2020.

Trumble, Benjamin C., and Caleb E. Finch. 2019. "The Exposome in Human Evolution: From Dust To Diesel." *The Quarterly Review of Biology* 94 (4): 333–94.

Tuana, Nancy. 2019. "Climate Apartheid: The Forgetting of Race in the Anthropocene." *Critical Philosophy of Race* 7 (1): 1–31.

United States Commission on Civil Rights (USCCR). 2019. *Briefing Report: Collateral Consequences: The Crossroads of Punishment, Redemption and the Effects on Communities*, Washington, DC: The United States Commission on Civil Rights. https://www.usccr.gov/pubs/2019/06-13-Collateral-Consequences.pdf. Accessed September 04, 2020.

United States Global Change Research Program. 2016. *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*, eds. Marcus C. Sarofim, Shubhayu Saha, Michelle D. Hawkins, David M. Mills, Jeremy J. Hess, Radley M. Horton, Patrick L. Kinney, Joel D. Schwartz, and Alexis St Juliana. Washington DC: U.S. Global Change Research Program. https://doi.org/10.7930/J0R49NQX. Accessed September 04, 2020.

United States Government Accountability Office (GAO). 2019. *Superfund: EPA Should Take Additional Actions to Manage Risks from Climate Change. October*, Washington, DC: The United States Government Accountability Office (GAO). https://www.gao.gov/assets/710/702158.pdf. Accessed September 04, 2020.

Venters, Homer. 2019. *Life and Death in Rikers*, Baltimore: Johns Hopkins University Press.

———. 2020. "Four Ways to Protect Our Prisons and Jails from the Coronavirus." *The Hill*. https://thehill.com/opinion/criminal-justice/485236-4-ways-to-protect-our-jails-and-prisons-from-coronavirus. Accessed September 04, 2020.

Vermeulen, Roel, Emma L. Schymanski, Albert-L. ászló Barabási, and Gary W. Miller. 2020. "The Exposome and Health: Where chemistry Meets biology." *Science* 367 (6476): 392–396.

Wacquant, Loïc. 2009. *Punishing the Poor: The Neoliberal Government of Social Insecurity*, Durham: Duke University Press.

———. 2010. "Class, Race & Hyperincarceration in Revanchist America." *Daedalus* 139 (3): 74–90.

Wahab, Stéphanie, and Meg Panichelli. 2013. "Ethical and Human Rights Issues in Coercive Interventions With Sex Workers." *Affilia* 28 (4): 344–349.

Wildeman, Christopher, and Emily A. Wang. 2017. "Mass Incarceration, Public Health, and Widening Inequality in The USA." *The Lancet* 389 (10077): 1464–74.

Watts, N., M. Amann, S. Ayeb-Karlsson, K. Belesova, T. Bouley, M. Boykoff, P., W. Cai et al. 2018. "The Lancet Countdown on Health and Climate Change: From 25 Years of Inaction to a Global Transformation for Public Health." *The Lancet* 391 (10120): 581–630.

Weible, C. M., D. Nohrstedt, P. Cairney, D. P. Carter, D. A. Crow, A. P. Durnová, T. Heikkila, K. Ingold, A. McConnell, and D. Stone. 2020. "COVID-19 and the Policy Sciences: Initial Reactions and Perspectives." *Policy Sciences*: 1–17. https://doi.org/10.1007/s11077-020-09381-4

Western, Bruce. 2018. *Homeward: Life in the Year After Prison*, New York: Russell Sage Foundation.

World Prison Brief. 2020. *Institute for Crime and Justice Policy Research* [Online]. https://www.prisonstudies.org/. Accessed September 04, 2020.

World Medical and Health Policy

# Techno-Economic Potential of Hybrid Renewable Energy Systems for Rural Health Units in the Philippines

**Allen Lemuel G. Lemence MSc and Mili-Ann M. Tamayao PhD**

*This study evaluated the techno-economic viability of utilizing a hybrid renewable energy system (HRES) in a standard rural healthcare facility in the Philippines to improve energy access and resiliency. The optimal configurations were determined to satisfy the electricity demand of the RHU while reducing the cost of energy (COE) by 37–42 percent and direct $CO_2$ emissions by ~59 percent. Both grid-connected and off-grid scenarios were considered. Results show that a solar photovoltaic panel-grid system is optimal for the grid-connected scenario while a solar photovoltaic panel-generator-battery system is optimal for the off-grid scenario. Most of the load was found to occur during daytime (specifically from 8:00 AM to 12:00 PM) and the optimal configurations are estimated to provide at least 70 percent of the facility's electricity demand. The results of this study support the policy of encouraging the integration of HRES in rural healthcare facilities in the Philippines as a way to augment energy access and increase energy system resilience while reducing long-term costs and $CO_2$ emissions.*

**KEY WORDS:** rural healthcare, hybrid renewable energy systems, energy system climate resilience, Philippines

## Introduction

In developing countries such as the Philippines, some remote areas still have poor energy access despite the increased electrification projects in recent decades. For example, energy access in the country's Mindanao region is only at 40.9 percent (Department of Energy, 2018). Climate change can further make the energy sector vulnerable across its entire chain—from resource extraction, transmission, up until consumption (Schaeffer et al., 2012). Numerous events have exposed how current energy systems are vulnerable to climate-induced natural disasters (Bundhoo, Shah, & Surroop, 2018; Panteli, Pickering, Wilkinson, Dawson, & Mancarella, 2017).

Power interruptions or a general lack of access to reliable electricity supply can particularly burden healthcare facilities. Without sufficient electricity, facilities may have their medical operations disrupted and be incapable of performing laboratory tests (Arvidson, Songela, & Syngellakis, 2006). They may also risk spoiling vaccines, fail to effectively sterilize medical equipment, and be unable to coordinate with better-equipped healthcare facilities, among others (GVEP International, 2013; US AID, 2011; World Health Organization, 2019). It has also been reported that lack of energy access makes pregnant women and children especially more vulnerable



doi: 10.1002/wmh3.388

(GVEP International, 2013; Porcaro et al., 2017). Overall, healthcare facilities are impacted negatively when exposed to power outages, including those connected to community or micro-grids, as reported by several studies (Austin, Martin, & Gregory, 2007; Klinger, Landeg, & Murray, 2014).

This study aims to contribute to exploring solutions to improve energy access and enhance the energy system resilience of healthcare facilities. In this context, the main objective of this study is to determine the techno-economic viability of a hybrid solar energy system in satisfying the electricity demand of RHUs in the Philippines, for a grid-connected and off-grid setup. Additionally, this study aims to estimate the possible reduction of $CO_2$ emissions of an RHU with such a system.

A climate-resilient energy is one that can provide "reliable, safe, and secure electricity during short-term disasters and events and as longer-term climate changes occur" (Cox et al., 2017). Diversifying energy resources enhances healthcare facilities' resiliency (Paterson, Berr, Ebi, & Varangu, 2014). This is where hybrid renewable energy systems (HRES) can step in. HRES, along with other models of distributed energy systems and microgrids can increase the energy infrastructure resilience of smaller-scale sectors or a particular facility (Cox et al., 2017; Hussain, Bui, & Kim, 2019). HRES, in particular, combines traditional and renewable energy technologies to address the limitations of each type (Al-Akori, 2014; Franco, Shaker, Kalubi, & Hostettler, 2017). Other configurations of HRES incorporate battery storage, which can make an energy system more flexible as it allows excess energy to be stored and then delivered at periods when energy is most needed (Olatomiwa, Mekhilef, & Ohunakin, 2016). Additionally, a resilient energy system helps reduce greenhouse gas emissions to supplement efforts to prevent future climate impacts.

There is a growing number of studies that explore the techno-economic potential of integrating HRES, specifically for rural electrification. These studies present findings related to the viability of HRES in satisfying the electricity demand of a specific site. For example, a study in a Cambodian rural community determined that a combination of solar photovoltaic (PV), diesel generator, and battery storage can reduce the cost of electricity (COE) paid by the community from 0.415 US dollars (USD) per kilowatt-hour (kWh) to 0.377 USD per kWh (Lao & Chungpaibulpatana, 2017). Another study concluded that a solar PV-wind turbine-diesel generator energy system can lower the COE of an Ethiopian rural community from 0.384 USD per kWh to 0.207 USD per kWh (Gebrehiwot, Mondal, Claudia, & Abiti, 2019). In both studies, integrating the HRES can also result in reduction of carbon dioxide ($CO_2$) emissions.

Despite the increasing research focused on HRES in the rural setting, few have explored its application in the context of rural healthcare facilities. Moreover, these research projects have only focused on Nigerian healthcare facilities (Babatunde, Adejoda, Babatunde, & Denwigwe, 2019; Esan et al., 2019; Olatomiwa, Blanchard, Mekhilef, & Akinyele, 2018; Oviroh & Jen, 2018; Salisu et al., 2019) and other countries in the Global South (Franco et al., 2017). These studies all conclude that shifting to HRES for the facilities will result to lower COE and $CO_2$ emissions.

In the Philippines, public rural healthcare facilities, such as rural health units (RHU), Barangay health stations, and district hospitals, are governed and managed by local government units. They operate under the policies and general direction set by the national government, through the Department of Health (DOH). In 2014, some off-grid RHUs in the country's Marinduque province have installed solar energy systems to augment their lack of energy supply (DOH MIMAROPA, 2017). However, relevant government agencies have yet to produce reports that evaluate the performance of such systems. A detailed assessment of such systems can help the national government achieve its recent plan to integrate alternative sources of energy for the healthcare facilities (Department of Health, 2019).

Overall, this study contributes to the growing research focused on renewable energy integration in the rural healthcare sector. It also supports the Philippine government's aim to utilize renewable energy sources to adapt to and mitigate the effects of climate change (Cruz et al., 2017).

## Methods

### *Overview*

The study was completed in four major steps. First, a representative Rural Health Unit (RHU) was selected. Second, the RHU energy consumption profile was estimated. This was followed by the simulation of different energy system configurations. Finally, from the simulations, an optimal energy system configuration was determined along with some sensitivity analyses.

Two scenarios were examined. The first scenario represents an RHU that is connected to the grid. The default energy system configuration for this is a grid-only energy system. The other energy system configurations considered for this scenario are a solar PV-grid system, a solar PV-grid-battery system, and a grid-battery system. The second scenario represents an RHU that is not connected to the grid and relies only on a standalone diesel generator for its electricity. In this scenario, the following energy system configurations were considered: a solar PV-generator system, a solar PV-generator-battery system, a solar PV-battery system, and a generator-battery system.

A schematic diagram of the possible energy system configuration in both scenarios is presented in Figure 1. These configurations include a combination of a solar PV array, a battery energy storage, the electricity grid (for the grid-connected scenario), the diesel generator (for the off-grid scenario), and an inverter. The inverter is used to convert direct current (DC) to an alternating current (AC), which is the current required by the electrical load. A hybrid energy system also has a system controller that manages which energy technologies to run depending on the dispatch strategy implemented.

### *Site Selection and Energy Consumption Profile*

The representative RHU chosen for this study is located in the Municipality of Los Baños, Laguna. According to Dr. Rene P. Bagamasbad of the Laguna Provincial

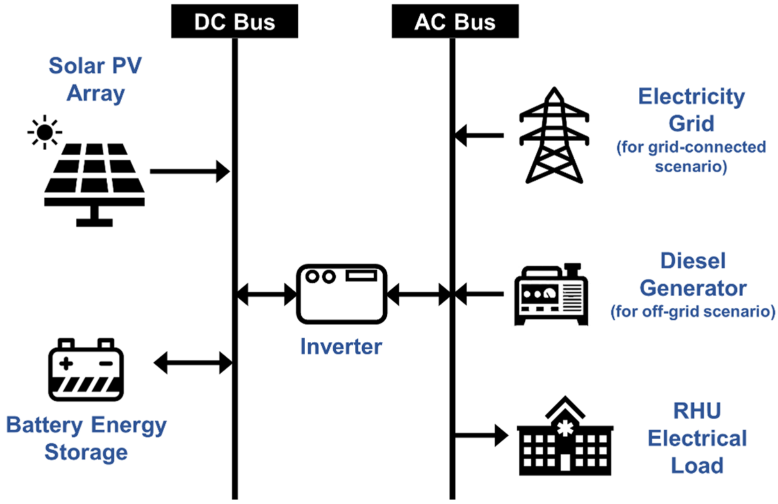



**Figure 1** Schematic Diagram of the Hybrid Solar Energy System.

Health Office, this RHU is relatively complete in terms of available medical services, per the requirements of the DOH.

The Los Baños RHU is located at 829 Manila South Road, Los Baños, 4030 Laguna, and has two buildings. The first is the main facility, which houses the administrative office and the majority of the medical services, including medical consultations, laboratory testing, treatment for animal bites, vaccinations, and dental services. The other building houses the birthing facility and consultation rooms for reproductive health and social hygiene. All medical services in the RHU, except for the services offered by the birthing facility, are available from Monday to Friday, from 8:00 AM to 5:00 PM. The birthing facility is open for 24 hours on all seven days of the week.

To estimate the RHU's energy consumption profile, a work sampling method was adopted for energy auditing. For each hour, each electricity-consuming equipment was checked if it was in use, on standby mode, or switched off. It was assumed the equipment held that same status for the entire hour window. To get the daily load consumed by a device, the hours of usage were multiplied by the wattage. The total daily load of the facility is the sum of the daily load of all devices. The complete list of devices in the Los Baños RHU is presented in Table 1.

For the weekday load profile, hourly observations from 8:00 AM to 5:00 PM were done for 1 week. Meanwhile, the weekend load profile assumed that only the devices in the birthing facility are in use in addition to devices that are constantly in use (namely, the vaccine refrigerators). Interviews with facility staff were conducted to verify and supplement the observations.

The authors allowed for 10 percent daily and 20 percent hourly variations to address accuracy limitations that may arise from the method described above. By allowing these variations, simulations randomly increased or decreased daily loads by up to 10 percent to change the load magnitude without changing its shape.

**Table 1.** List of Equipment in the Los Baños Rural Health Unit

| Equipment | Qty. | Wattage | Equipment | Qty. | Wattage |
|---|---|---|---|---|---|
| *RHU main building* | | | Printer 1 | 1 | 5[a] |
| Aircon 1 | 2 | 660 | Printer 2 | 5 | 8[a] |
| Aircon 2 | 1 | 535 | Printer 3 | 1 | 6.6[a] |
| Aircon 3 | 2 | 1,075 | Radio | 1 | 7 |
| Aircon 4 | 1 | 720 | Refrigerator | 2 | 435 |
| AVR | 1 | 250 | Stand Fan 1 | 4 | 65 |
| Biosafety Cabinet | 1 | 124 | Stand Fan 2 | 1 | 50 |
| Ceiling Fan | 1 | 75 | Typewriter | 1 | 80 |
| Centrifuge | 1 | 1,400 | UV Sterilizer | 1 | 500 |
| Computer 1 | 1 | 200 | Wall Fan | 5 | 45 |
| Computer 2 | 8 | 220 | Water Dispenser | 2 | 500 |
| Dental Chair | 1 | 374 | *Birthing facility* | | |
| Desk Fan | 2 | 45 | Aircon | 4 | 670 |
| Dry Heat Sterilizer | 1 | 450 | Computer | 1 | 220 |
| Exhaust Fan 1 | 1 | 32 | Hospital Bed | 2 | 24[a] |
| Exhaust Fan 2 | 2 | 12 | Lighting 1 | 104 | 28 |
| Gene Expert Machine | 2 | 350 | Lighting 2 | 4 | 12.5 |
| Industrial Fan | 1 | 350 | Lighting 3 | 4 | 33 |
| LED Microscope | 1 | 90 | Lighting 4 | 3 | 20 |
| Lighting 1 | 37 | 36 | Printer | 1 | 8[a] |
| Lighting 2 | 2 | 12.5 | Radio | 1 | 12 |
| Medical Refrigerator | 1 | 124 | Stand Fan | 3 | 65 |
| Micro Hematocrit Centrifuge | 1 | 1,386 | TV | 1 | 140 |
| Microscope | 1 | 150 | Vaccine Refrigerator | 1 | 124 |
| Mini Fan | 6 | 10 | Water Dispenser | 1 | 500 |

[a]Wattage in standby mode.

The simulations also randomly increased or decreased hourly loads by up to 20 percent to change the load shape without changing its magnitude.

### *Modeling and Optimization*

This study used the Hybrid Optimization of Multiple Energy Resources (HOMER) Pro software to simulate the different energy system configurations. Five main categories comprise the inputs to the simulations, namely: resources data, energy load profile, component data, system economics, and constraints. HOMER Pro uses these input data to produce the following outputs: system architecture, costs, and other system parameters. The structure of the HOMER Pro simulation process is presented in Figure 2.

For each configuration, HOMER Pro calculates the total net present cost (NPC), annualized cost, and cost of energy (COE). The configuration with the lowest total NPC is chosen as the optimal configuration. Total NPC is the sum of the present value of all system costs across the project lifetime deducted by the present value of all revenues during the same period. HOMER Pro uses the Total NPC to compute the annualized costs and cost of energy. Additionally, the software computes for the return on investment (ROI), internal rate of return (IRR), and payback period, which are metrics that can aid in decision making.

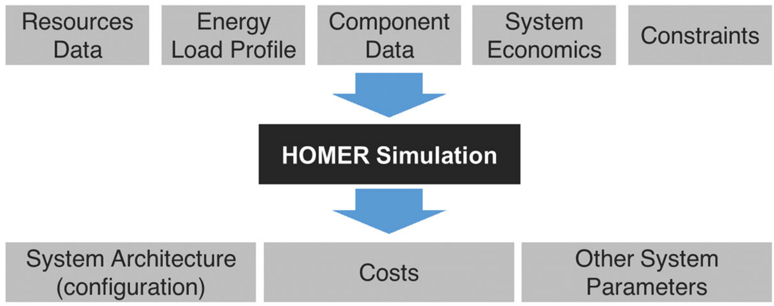



**Figure 2** HOMER Pro Simulation Structure.

Relevant formulae performed in the software are presented in Appendix A. Readers who are interested in further studying the software's equations and other mathematical models are directed to the HOMER Pro guide at homerenergy.com/products/pro/docs/latest/index.html.

*Resources Data*

The relevant energy resources for this study are the solar global horizontal irradiation (GHI), clearness index, and temperature, which all influence the energy output of solar PV panels. The solar GHI represents the amount of energy coming from the sun, the clearness index represents the clearness of the earth's atmosphere to transmit the sun's energy to the earth's surface, and the temperature influences the panels' energy conversion efficiency. The solar GHI values were retrieved from the National Agrometeorological Station of the University of the Philippines Los Baños, which is in the same municipality as the selected health facility. Meanwhile, the clearness index and temperature were adopted from the Surface Meteorology and Solar Energy database of NASA.

The average monthly solar GHI and clearness index values for a year are shown in Figure 3. The solar GHI represents a scaled daily average of 5.00 kWh per square meter ($m^2$). Meanwhile, the average monthly temperature is shown in Figure 4. This represents a scaled average of 25.82°C.

*Component Data*

A summary of all component data used in this study is shown in Table 2. Wherever applicable, Philippine peso (PHP) was converted to US dollars (USD) using 50.00PHP = 1.00 USD conversion factor.

For the solar PV component, costs and efficiency were adopted from a report of the US National Renewable Energy Laboratory (NREL) about solar PV panel parameters (Fu, Feldman, & Margolis, 2018a). The capital and replacement costs were computed using the report's values, details about this computation are found in Appendix B. The study adopted the software's default values for panel efficiency,

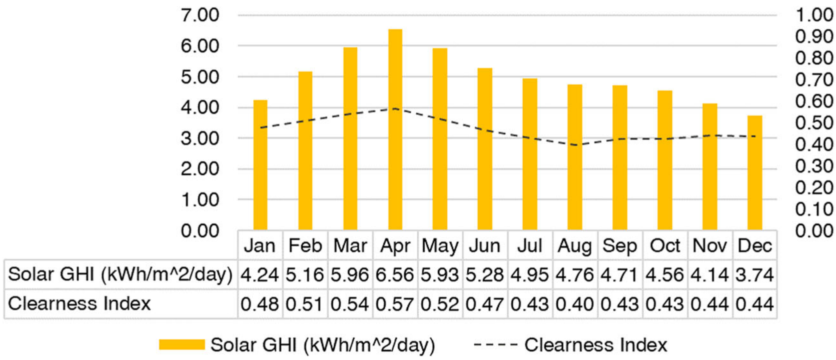



**Figure 3** Average Monthly Solar Global Horizontal Irradiation (GHI) and Clearness Index for the Selected Site.

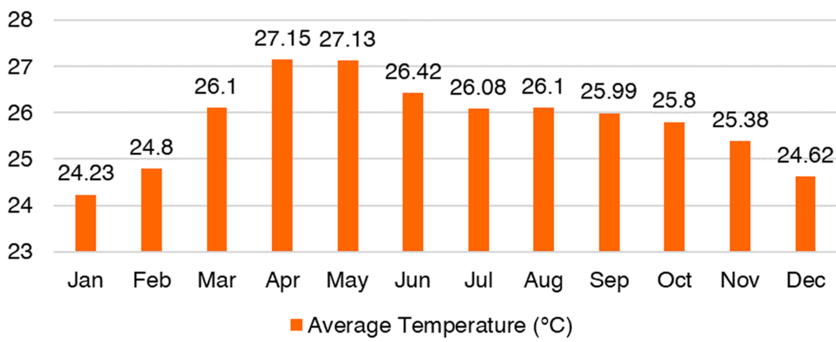



**Figure 4** Average Monthly Temperature in the Selected Site.

nominal operating cell temperature, derating factor, ground reflectance, and temperature effects on power output.

The battery component used in this study was assumed to be a lithium-ion (li-ion) type with a lifetime of 15 years. The capital and replacement costs of each unit were the computed average of the costs presented in an NREL publication on energy storage costs (Ardani et al., 2017). Other values, as presented in Table 2, were adopted from a study on hybrid energy system transition in Philippine island grids (Ocon & Bertheau, 2019).

The costs and efficiency of the inverter component were adopted from several studies (IRENA, 2016; Lau, Tan, & Yatim, 2015; Olatomiwa et al., 2018). The component has a lifetime of 15 years and its efficiency was set to the default value.

The diesel generator's costs were adopted from a similar study set in off-grid Nigerian healthcare facilities (Olatomiwa et al., 2018). All other input variables for the generator component adopted the values of HOMER Pro for the "Autosize Generator" component found within the software.

The price of diesel fuel used to operate the generator was set to 0.8417 USD/liter, which represents the grand average of the end-of-month average prices of

**Table 2.** Technical and Economic Data for the Components of the Hybrid Energy System

| | | | |
|---|---|---|---|
| *Solar photovoltaic (PV) panel* | | *Inverter* | |
| Lifetime | 25 years | Lifetime | 15 years |
| Capital and replacement costs | 1,870.78 /kW | Capital and replacement costs | 180/kW |
| O&M costs | 18/kW | O&M costs | 10/year |
| Efficiency | 19.1% | Efficiency | 90% |
| Nominal cell temperature | 47°C | *Diesel generator* | |
| Derating factor | 80% | Lifetime | 15,000 hours |
| Ground reflectance | 20% | Capital and replacement costs | 200/kW |
| Temperature effects on power | −0.5%/°C | O&M costs | 0.05/hour |
| *Battery* | | Diesel fuel price | 0.8417/liter |
| Lifetime | 15 years | Diesel carbon content | 88% |
| Capital and replacement costs | 2,043/unit | *Electricity grid* | |
| O&M costs | 7.25/kWh/year | Grid power price | 0.1948/kWh |
| Maximum C-rate | 0.5 kW/kWh | Grid sellback price | 0.1045/kWh |
| Maximum depth of discharge | 80.00% | $CO_2$ emission factor | 646.09 $gCO_2$/kWh |
| Charging efficiency | 90.00% | *Controller* | |
| Discharging efficiency | 90.00% | Cycle charging: load following, and combined dispatch strategies | |
| Round trip efficiency | 81.00% | | |

*Note*: All costs are in USD.

diesel from different retailers in Laguna, Philippines for 2019 (Department of Energy, n.d.a). The diesel fuel's carbon content was set to the software's default value (HOMER Energy, n.d.).

The grid power price was set to 0.1948 USD/kWh, which represents the average price paid by the RHU for the period of March to October 2019. Meanwhile, the grid sellback price was set to 0.1045 USD/kWh. This is the computed 2019 average generation rate from of the Manila Electric Company (MERALCO, n.d.) and represents the amount that the facility can earn when it sells electricity back to the grid under a net metering program. For this study, the net purchases from net metering were set to be calculated monthly. The grid's $CO_2$ emission factor was set to the value published by the Philippine Department of Energy (Department of Energy, n.d.b).

Lastly, the study considered cycle charging, load following, and combined dispatch strategies for the simulations. In cycle charging, the generator operates at full capacity when supplying energy. Excess energy is directed to applicable deferred load or battery charging. Meanwhile, in the load following strategy, the generator operates only at the level required by the primary load. Deferred load or battery charging is supplied by renewable energy sources. The generator can still produce energy and sell it to the grid if it is financially favorable. The combined dispatch strategy chooses between cycle charging or load following in each timestep.

### *System Economics and Constraints*

The project lifetime was set to 25 years. The inflation rate was set to 3.2 percent, which is the inflation rate in the Philippines for 2019 (Philippine Statistics

**Table 3.** System Economics and Constraints

| Parameter | Value |
|---|---|
| Project lifetime | 25 years |
| Expected inflation rate | 3.2% |
| Nominal discount rate | 10.00% |
| Maximum annual capacity shortage | 0.00% |
| Minimum renewable fraction | 0.00% |
| *Operating reserve* | |
| As a percentage of load: load in current time step | 10.00% |
| As a percentage of load: annual peak load | 0.00% |
| As a percentage renewable output: solar power output | 80.00% |

Authority, 2020). Meanwhile, the discount rate was set to 10 percent, which is the social discount rate prescribed by the Philippines' National Economic and Development Authority (National Economic and Development Authority, 2016).

The system was set to have no maximum annual capacity shortage. This signifies that there should be electricity all throughout the year and dictates that HOMER Pro will only recommend energy system configurations that are expected to have no power shortage. The minimum renewable fraction was also set to 0 percent so that the simulations will still include energy system configurations without renewable technology if it is techno-economically feasible. Finally, the default values for operating reserve were used. The simulation's system economics and constraints are summarized in Table 3.

## *Sensitivity Analysis*

Sensitivity analysis was conducted to explore the impacts to the optimal configuration of changes in solar GHI, ambient temperature, inflation rate, diesel price, and capital and replacement costs for the solar PV and battery components. Each sensitivity variable was varied by ±10 and ±20 percent. The final values considered are summarized in Table 4.

The values presented in Table 4 are reasonable as most coincide with or cover values found in the literature. For example, the average scaled solar GHI is estimated to be 4.50 and 5.50 kWh/m$^2$/day, respectively, in the northern and southern

**Table 4.** Sensitivity Variables Considered in the Study

| Parameter | −20% | −10% | Base Value | 10% | 20% |
|---|---|---|---|---|---|
| Solar GHI (kWh/m$^2$/day) | 4.00 | 4.50 | 5.00 | 5.50 | 6.00 |
| Temperature (°C) | 20.66 | 23.24 | 25.82 | 28.40 | 30.98 |
| Inflation rate (%) | 1.00% | | 3.20% | 4.20% | |
| Diesel price (USD/L) | 0.6734 | 0.7575 | 0.8417 | 0.9259 | 1.0100 |
| Solar PV costs (USD/kW) | 1,496.62 | 1,683.70 | 1,870.78 | 2,057.86 | 2,244.94 |
| Battery costs (USD/unit) | 1,634.40 | 1,838.70 | 2,043.00 | 2,247.30 | 2,451.60 |

*Note*: GHI, global horizontal irradiation; PSV, photovoltaic.

parts of the Philippines (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, 2013). Note that for both solar GHI and temperature, changing the base value—which is the scaled annual average—would also change the monthly average accordingly to retain the shapes presented in Figures 3 and 4.

Likewise, the lowest and highest average diesel price recorded in Laguna were 0.8049 and 0.8766 USD/L, respectively (Department of Energy, n.d.a). Similarly, the range of battery costs considered in the sensitivity analysis also covers the lowest and highest costs presented in the NREL publication (Ardani et al., 2017).

The inflation rate was exempted from the considered percentage decrements and increments because the values would not cover the minimum and maximum inflation rate recorded in the country in the past five years. Therefore, a low and high inflation rate was set to 1.0 and 4.2 percent, respectively, which are the lowest and highest average inflation rates in the country from 2015 to 2019 (Philippine Statistics Authority, 2020).

Finally, a set of simulations excluding birthing facility load was conducted. This was done because birthing facilities are not required in the standard design of an RHU in the Philippines.

## Results and Discussion

This study evaluated the techno-economic viability of integrating an HRES in satisfying the electricity requirements of a standard RHU in the Philippines. The optimal configurations were determined to satisfy the electricity demand of the RHU at the lowest total net present cost (NPC) and the cost of energy (COE). Both grid-connected and off-grid scenarios were considered. The results indicate that the optimal configuration is a combination of solar PV-grid system for the grid-connected scenario and a solar-PV-battery-generator system for the off-grid scenario. The simulations show that the solar component of the optimal configurations in both the grid-connected and off-grid scenarios can satisfy at least half of the total load required by the facility. Most of the load occurs during the daytime (specifically from 8:00 AM to 12:00 PM), the period when high solar PV output is expected. Moreover, HRES will reduce RHU carbon dioxide emissions, contributing to the climate change mitigation pathway of the country.

### *Load Profile*

During weekdays, peak loads occur from around 8:00 AM to 12:00 PM, when most medical services are in operation. During weekends, no noticeable peak is observed since most of the facility's functions are not in operation except for the birthing facility. Across the year, and when the daily and hourly variations have been applied, the facility is estimated to have a scaled average daily consumption of 139.95 or 51,081.75 kWh/year. Estimated hourly load profiles for a typical weekday and weekend are shown in Figure 5. The more detailed, typical hourly profile is shown in Appendix C.

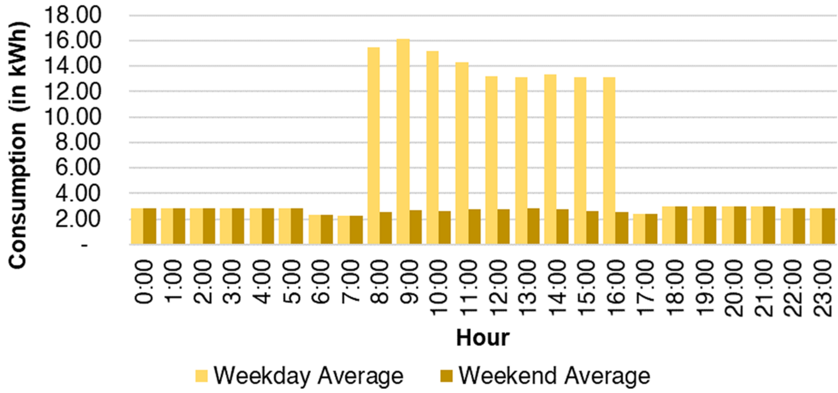



**Figure 5** Hourly Load Profile of the Los Baños RHU.

*Optimal Configuration*

The results of the simulations indicate that the optimal configuration for a grid-connected RHU is a combination of a 44-kW solar PV, the grid, and a 26.85-kW inverter. This configuration follows a cycle charging dispatch strategy and has a renewable fraction of ~72 percent and this is discussed further in the subsequent section. Implementing the optimal configuration is estimated to have a total NPC that is 16 percent lower compared to the base case of a grid-only system. Consequently, the COE is also lower by ~42 percent. This can be attributed to the lower annual operation and maintenance costs—the base configuration costs 9,950 USD per year while the optimal configuration costs only 1,105 USD per year.

However, the optimal configuration will initially cost 87,139 USD while retaining the base configuration will not incur any capital costs. A more complete comparison of the optimal configuration with the base case and other system configurations is shown in Table 5.

For the off-grid RHU, the optimal configuration is a combination of a 41.22-kW solar PV, 29 units of battery, a 29-kW diesel generator, and a 22.86-kW inverter. This configuration follows a combined dispatch strategy and has a renewable fraction of ~54 percent. Both the total NPC and COE of this configuration is ~37 percent lower compared to the generator-only system. This can also be attributed to the lower operation and maintenance costs—15,549 USD yearly for the optimal configuration and 29,206 USD yearly for the base configuration.

Initial capital of 146,283.80 USD is required to implement the optimal system for off-grid RHU. Meanwhile, the base system will cost 104,244 USD. A more complete comparison of the optimal configuration with the base case and other configurations is shown in Table 6.

The next comparable configuration for the off-grid scenario is the battery-generator system, where the NPC and COE is about 21% lower than the base case. This configuration might be more attractive to stakeholders because its initial capital is only about half of what is required for the solar-PV-battery-generator

**Table 5.** Comparison of Energy System Configurations for the Grid-Connected Scenario

| | Architecture | | | | |
|---|---|---|---|---|---|
| Configuration | PV (kW) | 1 kWh LI (units) | Grid (kW) | Inverter (kW) | Dispatch Strategy |
| SPV-G | 44.00 | | 999,999 | 26.85 | Cycle charging |
| SPV-B-G | 43.82 | 1 | 999,999 | 26.50 | Load following |
| G* | | | 999,999 | | Cycle charging |
| B-G | | 1 | 999,999 | 0.21 | Load following |

| | Costs | | | | System |
|---|---|---|---|---|---|
| Configuration | NPC (USD) | COE (USD/kWh) | O&M (USD/year) | Initial Capital (USD) | Renewable Fraction (%) |
| SPV-G | 100,514.60 | 0.1125 | 1,105.54 | 87,139.49 | 71.91 |
| SPV-B-G | 103,293.50 | 0.1160 | 1,199.24 | 88,785.20 | 71.77 |
| G* | 120,383.10 | 0.1948 | 9,950.73 | 0.00 | 0.00 |
| B-G | 123,234.70 | 0.1994 | 10,014.46 | 2,080.50 | 0.00 |

*Note*: The grid component was set to 999,999 kW to simulate "infinite" capacity. *, base case; B, battery; G, grid; SPV, solar PV panel.

**Table 6.** Comparison of Energy System Configurations for the Off-Grid Scenario

| | Architecture | | | | |
|---|---|---|---|---|---|
| Configuration | PV (kW) | 1kWh LI (units) | Generator (kW) | Inverter (kW) | Dispatch Strategy |
| SPV-B-Gen | 41.22 | 29 | 29 | 22.86 | Combined dispatch |
| B-Gen | | 34 | 29 | 9.24 | Cycle charging |
| SPV-Gen | 50.37 | | 29 | 23.43 | Combined dispatch |
| Gen* | | | 29 | | Cycle charging |

| | Costs | | | | System | |
|---|---|---|---|---|---|---|
| Configuration | NPC (USD) | COE (USD/ kWh) | O&M (USD/year) | Initial capital (USD) | Renewable Fraction (%) | Fuel (L/year) |
| SPV-B-Gen | 334,399.40 | 0.5411 | 15,549.42 | 148,283.80 | 53.83 | 9,017 |
| B-Gen | 417,830.30 | 0.6761 | 28,178.78 | 76,925.53 | 0.00 | 20,044 |
| SPV-Gen | 457,585.00 | 0.7404 | 29,206.73 | 102,244.30 | 3.76 | 21,073 |
| Gen* | 534,375.30 | 0.8647 | 43,691.41 | 5,800.00 | 0.00 | 32,999 |

*Note*: *, base case; B, battery; Gen, diesel generator; SPV, solar PV panel.

system. However, the operating and maintenance costs are higher compared to the optimal configuration.

### *Energy Production*

In both scenarios, the solar PV component of the optimal configuration is expected to contribute at least 70% to the total energy production, with the remainder coming either from grid purchases or from the diesel generator. The energy production of each

**Table 7.** Energy Production of the Components of the Optimal Energy System Configurations

| Grid-Connected Scenario | | | Off-Grid Scenario | | |
|---|---|---|---|---|---|
| Component | Production (kWh) | Production (%) | Component | Production (kWh) | Production (%) |
| Solar PV | 59,358 | 74.10% | Solar PV | 55,618 | 70.22% |
| Grid | 20,748 | 25.90% | Diesel Generator | 23,587 | 29.78% |
| Total | 80,106 | 100% | Total | 79,205 | 100% |

component in both scenarios is shown in Table 7. Detailed performance of the grid in the grid-connected scenario is shown in Table 8. It can be observed that the net annual energy charge is -81.26 USD. This indicates that the overall grid performance generates cash inflow for the system instead of additional costs.

The renewable fractions presented in Tables 5 and 6 indicate the portion of the facility's total load that is supplied by renewable energy. This is computed as one less the ratio of the non-renewable energy production to the total load of the facility plus grid sales (for the grid-connected scenario). Recall that the total load of the facility is 51,082 kWh, while the computed grid sales for the optimal configuration in the grid-connected scenario amounts to 22,776 kWh. This means that excess energy produced by the optimal configuration can be sold back to the grid and/or offset future grid consumption costs of the facility.

### *Financial Performance*

The investment required to implement the optimal configuration in the grid-connected scenario would take 9.7 years to be recovered. The estimated return on investment (ROI) is 6.10 percent while the internal rate of return (IRR) is 9.00 percent.

**Table 8.** Grid Performance in the Grid-Connected Scenario

| Month | Energy Purchased (kWh) | Energy Sold (kWh) | Net Energy Purchased (kWh) | Energy Charged (USD) |
|---|---|---|---|---|
| January | 1,934 | 1,848 | 86 | 16.70 |
| February | 1,420 | 2,062 | −642 | −67.05 |
| March | 1,560 | 2,508 | −948 | −99.02 |
| April | 1,254 | 2,523 | −1,269 | −132.63 |
| May | 1,522 | 2,128 | −606 | −63.31 |
| June | 1,699 | 1,711 | −11 | −1.19 |
| July | 1,743 | 1,634 | 109 | 21.32 |
| August | 2,008 | 1,540 | 467 | 90.99 |
| September | 1,737 | 1,699 | 38 | 7.47 |
| October | 1,821 | 1,716 | 105 | 20.49 |
| November | 2,041 | 1,771 | 270 | 52.58 |
| December | 2,009 | 1,637 | 372 | 72.39 |
| Annual | 20,748 | 22,776 | −2,028 | −81.26 |

**Table 9.** Carbon Dioxide Reduction Potential of the Optimal Energy System Configurations

| | Annual Emissions (kg $CO_2$/year) | | | |
|---|---|---|---|---|
| Scenario | Optimal Config. | Base Config. | Reduction | Percent Reduction |
| Grid-Connected | 13,405 | 33,003 | 19,598 | 59.38% |
| Off-Grid | 23,603 | 86,379 | 62,776 | 72.68% |

On the other hand, the optimal configuration in the off-grid scenario has a payback period of 4.5 years. Its ROI and IRR are 15.90 and 20.80 percent, respectively. The acceptability of these values relies on the criteria of relevant stakeholders.

### *Carbon Dioxide Reduction Potential*

As energy production in the optimal configuration is dominated by the solar PV component, system $CO_2$ emissions are reduced. The estimated $CO_2$ reduction in the grid-connected scenario is 59 percent (from 33,003 to 13,405 kg-$CO_2$/year). For the off-grid scenario, the reduction is higher at 72 percent (from 86,379 to 23,603 kg $CO_2$/year). These values are summarized in Table 9.

### *Results of Sensitivity Analysis*

In the grid-connected scenario, the sensitivity analysis reveals that the optimality of a solar PV and grid system is robust up to ±20 percent change in parameter values. The COE decreases further when solar GHI or inflation rate is higher, as well as when temperature or solar PV costs are lower. The COE increases at a low inflation rate, high component costs, hotter temperatures, or reduced solar GHI. There were no observed changes in both NPC and COE in either value of battery costs, indicating that the optimal configuration is not sensitive to battery prices. The resulting COE values in each sensitivity variable considered are shown in Table 10 and in Figure 6.

For the off-grid scenario, across all values of the sensitivity variables, the solar PV-generator-battery system remains optimal. The COE is expected to be lower at higher solar GHI, higher inflation rate, lower diesel prices, and cheaper component costs. The results of the sensitivity analysis for this scenario are presented in Table 11 and in Figure 7.

The optimal configurations also stand when considering a health unit without the estimated load of a birthing facility, which is 91.52 kWh/day or 33,405 kWh/year (the typical weekday and weekend load profile are shown in Figure 8). In a grid-connected scenario, a solar PV and grid system remains optimal. However, the system will have a lower capacity at 28.67-kW solar PV and at 17.53-kW inverter. In the off-grid scenario, the solar PV-battery-generator system also remains optimal. Similarly, the system capacity is lower: 33.63-kW solar PV, 25 units of battery, 23-kW generator, and 17.79-kW inverter. Other parameters of this sensitivity case are presented in Appendix D.

**Table 10.** Results of the Sensitivity Analysis for the Grid-Connected Scenario

| | Cost of Energy (USD/kWh) | | | | |
|---|---|---|---|---|---|
| Sensitivity Variable | −20% of Base Input Value | −10% of Base Input Value | Base Input Value | +10% of Base Input Value | +20% of Base Input Value |
| Solar GHI | 0.1533 | 0.1320 | 0.1125 | 0.1031 | 0.0963 |
| Temperature | 0.1097 | 0.1113 | 0.1125 | 0.1154 | 0.1238 |
| Inflation rate | 0.1501 | | 0.1125 | 0.1024 | |
| Solar PV costs | 0.0925 | 0.1020 | 0.1125 | 0.1308 | 0.1433 |
| Battery costs | 0.1125 | 0.1125 | 0.1125 | 0.1125 | 0.1125 |

*Note*: For inflation rate, the values considered were 1.00% and 4.20% for the lower and higher value, respectively. GHI, global horizontal irradiation; PSV, photovoltaic.

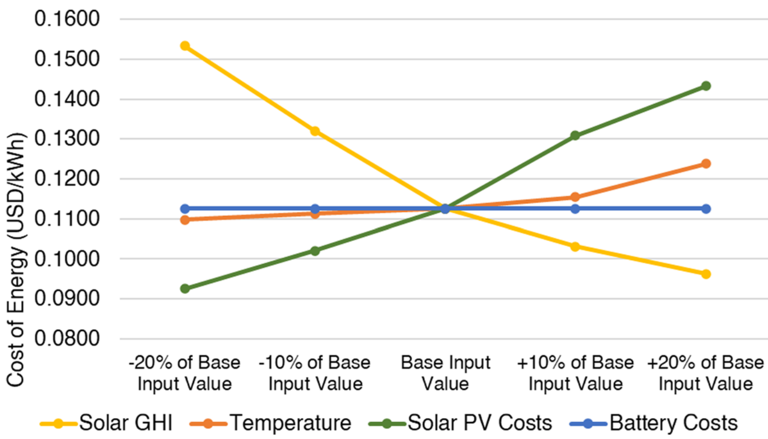



**Figure 6** Results of the Sensitivity Analysis for the Grid-Connected Scenario.

**Table 11.** Results of the Sensitivity Analysis for the Off-Grid Scenario

| | Cost of Energy (USD/kWh) | | | | |
|---|---|---|---|---|---|
| Sensitivity Variable | −20% of Base Input Value | −10% of Base Input Value | Base Input Value | +10% of Base Input Value | +20% of Base Input Value |
| Solar GHI | 0.5736 | 0.5560 | 0.5411 | 0.5285 | 0.5186 |
| Temperature | 0.5374 | 0.5392 | 0.5411 | 0.5428 | 0.5448 |
| Diesel price | 0.5102 | 0.5259 | 0.5411 | 0.5561 | 0.5718 |
| Inflation rate | 0.5889 | | 0.5411 | 0.5205 | |
| Solar PV costs | 0.5161 | 0.5291 | 0.5411 | 0.5536 | 0.5655 |
| Battery costs | 0.5102 | 0.5249 | 0.5411 | 0.5597 | 0.5733 |

*Note*: For the inflation rate, the values considered were 1.00% and 4.20% for the lower and higher value, respectively. GHI, global horizontal irradiation; PSV, photovoltaic.

### *Policy Implications*

The results of this study support the policy to encourage the integration of HRES in rural healthcare facilities (e.g., RHUs in the Philippines) as a way to

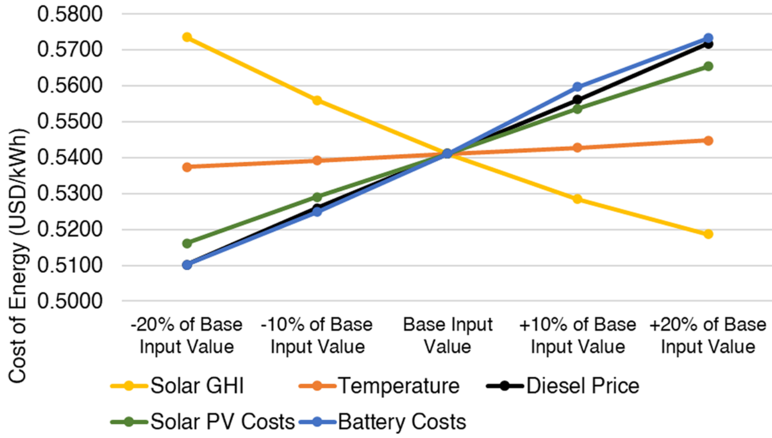



**Figure 7** Results of the Sensitivity Analysis for the Off-Grid Scenario.

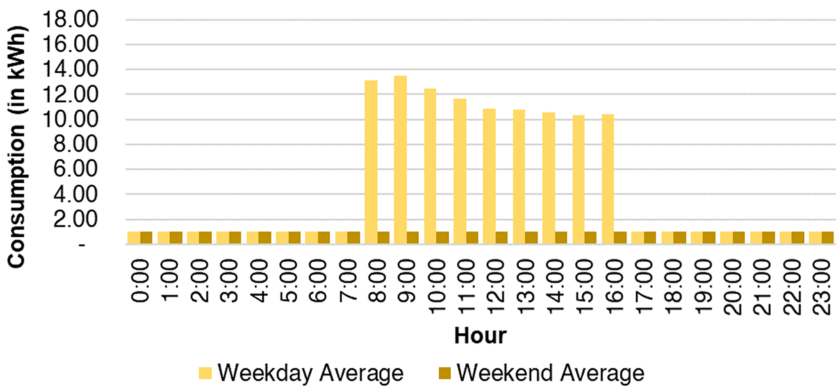



**Figure 8** Hourly Load Profile of the Los Baños RHU (Without Birthing Facility Load).

augment energy access and increase energy system resilience. The Philippine Department of Health and local government units may find the results of this study relevant in planning for construction of future RHUs as well as budgeting for potential improvements in existing RHUs across the country. In particular, findings from this study support the initial efforts of DOH to integrate alternative energy resources to primary care facilities in the country. The results of this study can be related to existing grid-connected RHUs as well as planned RHUs that might be built in off-grid areas. Local government units can also use the findings of this study in budget planning for RHUs within their jurisdictions. Although initial costs can be daunting, this study shows that reduction in long-term recurring costs as well as the reduced dependence on the grid or diesel fuel justify the investment. Available financing mechanisms, offered through climate-related efforts of banks and international financing institutions may also be explored.

### *Limitations and Future Studies*

The study primarily focused on the selected facility in Los Baños, Laguna. Thus, certain characteristics were location-specific, such as solar energy parameters and temperature. In the specific facility, only solar energy installation was considered feasible. However, other renewable energy technologies may also compose HRES; for example, hydropower plants or wind turbines—which will depend on the facility's location. These variations may be explored in future studies.

Future studies may consider the effects of year-on-year changes on costs, energy resources, facility load, and other variables. Furthermore, the probability of power outages can be considered in designing HRES for grid-connected facilities. Finally, analysis for off-grid areas can also compare the costs of setting up an HRES versus the costs of grid expansion.

**Allen Lemuel G. Lemence** obtained his master's degree in energy engineering from the University of the Philippines Diliman and is currently engaged in an energy system planning research project for the Philippines.

**Mili-Ann M. Tamayao** obtained her postdoc and PhD in engineering from the Carnegie Mellon University, PA and is currently an Associate Professor at the University of the Philippines focusing on research in sustainable health and energy.

## Notes

The authors would like to thank the Kingson Management and Development Corporation, and the University of the Philippines Engineering Research and Development Foundation, Inc. for providing financial support to conduct and disseminate this study.

Conflicts of interest: None declared.

**Corresponding author**: Allen Lemuel G. Lemence, aglemence1@up.edu.ph

## References

Al-Akori, Adnan. 2014. *PV Systems for Rural Health Facilities in Developing Areas—A Completion of Lessons Learned* [Online]. https://iea-pvps.org/wp-content/uploads/2020/01/IEA-PVPS_T9-15_2014_PV_for_rural_health_facilities.pdf

Ardani, Kristen, Eric O'Shaughnessy, Ran Fu, Chris McClurg, Joshua, Huneycutt, and Robert Margolis. 2017. *Installed Cost Benchmarks and Deployment Barriers for Residential Solar Photovoltaics with Energy Storage: Q1 2016* [Online]. NREL Technical Report. https://www.nrel.gov/docs/fy17osti/67474.pdf

Arvidson, Anders, Francis Songela, and Katerina Syngellakis. 2006. *The Role of Energy Services in the Health, Education and Water Sectors and Cross-Sectoral Linkages* [Online]. https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/enable_cross_sectoral_linkages.pdf

Austin, Zubin, J. Craig Martin, and Paul A. M. Gregory. 2007. "Pharmacy Practice in Times of Civil Crisis: The Experience of SARS and 'the Blackout' in Ontario, Canada." *Research in Social and Administrative Pharmacy* 3 (3): 320–35.

Babatunde, Olubayo Moses, Oluwaseye Samson Adejoda, Damilola Elizabeth Babatunde, and Iheanacho Henry Denwigwe. 2019. "Off- Grid Hybrid Renewable Energy System for Rural Healthcare Centers: A Case Study in Nigeria." *Energy Science and Engineering* 7 (13): 676–93. https://onlinelibrary.wiley.com/doi/full/10.1002/ese3.314

Bundhoo, Zumar M. A., Kalim U. Shah, and Dinesh Surroop. 2018. "Climate Proofing Island Energy Infrastructure Systems: Framing Resilience Based Policy Interventions." *Utilities Policy* 55 (March): 41–51.

Cox, Sadie, Eliza Hotchkiss, Dan Bilello, Alison Holm, and Jennifer Leisch. 2017. *Bridging Climate Change Resilience and Mitigation in the Electricity Sector Through Renewable Energy and Energy Efficiency: Emerging Climate Change and Development Topics for Energy Sector Transformation*. US AID.

Cruz, Rex Victor O, Porfirio M. Aliño, Olivia C. Cabrera, Carlos Primero C., David, Laura T. David, Felino P. Lansigan, and Rodel D. Lasco. 2017. *2017 Philippine Climate Change Assessment: Impacts, Vulnerabilities and Adaptation*. The Oscar M. Lopez Center for Climate Change Adaptation and Disaster Risk Management Foundation, Inc. and Climate Change Commission: 168. https://climate.gov.ph/files/PhilCCA-WG2.pdf

Department of Energy. 2018. *Sectoral Plans and Roadmaps 2017-2040* [Online]. https://www.doe.gov.ph/sites/default/files/pdf/pep/pep_volume_2_sectoral_plans_and_roadmaps.pdf

Department of Energy. n.d.a. *South Luzon Prevailing Retail Pump Prices* [Online]. https://www.doe.gov.ph/retail-pump-prices-south-luzon?q=retail-pump-prices-south-luzon&ckattempt=1. Accessed February 11, 2020b.

Department of Energy. n.d.b. *2015-2017 National Grid Emission Factor (NGEF)*. https://www.doe.gov.ph/electric-power/2015-2017-national-grid-emission-factor-ngef. Accessed November 14, 2019a.

Department of Health. 2019. *Manual of Standards for Primary Care Facilities Rural Health Unit/Urban Health Unit/Health Center and Barangay Health Station*.

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. 2013. *It's More Sun in the Philippines: Facts and Figures on Solar Energy in the Philippines*. https://www.giz.de/fachexpertise/downloads/giz2012-en-pv-in-the-philippines-policy-brief.pdf/. Accessed December 6, 2019.

DOH Mimaropa. 2017. *DOH MIMAROPA Pushes for More Solar Powered Rural Health Stations in the Region* [Online]. http://www.ro4b.doh.gov.ph/index.php/media-releases/press-release/896-doh-mimaropa-pushes-for-more-solar-powered-rural-health-stations-in-the-region. Accessed November 5, 2019.

Esan, A. B., A. F. Agbetuyi, O. Oghorada, K. Ogbeide, A. A. Awelewa, and A. E. Afolabi. 2019. "Reliability Assessments of an Islanded Hybrid PV-Diesel-Battery System for a Typical Rural Community in Nigeria." *Heliyon* 5 (5): e01632. https://doi.org/10.1016/j.heliyon.2019.e01632

Franco, Andrea, Marjan Shaker, Dikolela Kalubi, and Silvia Hostettler. 2017. "A Review of Sustainable Energy Access and Technologies for Healthcare Facilities in the Global South." *Sustainable Energy Technologies and Assessments* 22: 92–105.

Fu, Ran, David Feldman, and Robert Margolis. 2018a. *U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018* [Online]. NREL. https://www.nrel.gov/docs/fy19osti/72399.pdf

———. 2018b. *U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018* [Online]. NREL. https://www.nrel.gov/docs/fy16osti/66532.pdf

Gebrehiwot, Kiflom, Md. Alam Hossain Mondal, Ringler Claudia, and Getaneh Gebremeskel Abiti. 2019. "Optimization and Cost-Benefit Assessment of Hybrid Power Systems for off-Grid Rural Electrification in Ethiopia." *Energy* 177: 234–46.

GVEP International. 2013. *Low Carbon Studies Powering the Health Sector—Annex A—Literature Review* [Online]. https://assets.publishing.service.gov.uk/media/57a08a09e5274a31e00003ba/61311-LiteratureReview.pdf. Accessed December 5, 2019.

HOMER Energy. n.d. *How HOMER Calculates Emissions* [Online]. https://www.homerenergy.com/products/pro/docs/3.13/how_homer_calculates_emissions.html. Accessed February 12, 2020.

Hussain, Akhtar, Van Hai Bui, and Hak Man Kim. 2019. "Microgrids as a Resilience Resource and Strategies Used by Microgrids for Enhancing Resilience." *Applied Energy* 240 (February): 56–72.

IRENA. 2016. *The Power to Change: Solar and Wind Cost Reduction Potential to 2025* [Online]. International Renewable Energy Agency. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Power_to_Change_2016.pdf. Accessed January 12, 2020.

Klinger, Chaamala, Owen Landeg, and Virginia Murray. 2014. "Power Outages, Extreme Events and Health: A Systematic Review of the Literature from 2011-2012." *PLoS Currents* (JAN): 1–24.

Lao, Chhunheng, and Supachart Chungpaibulpatana. 2017. "Techno-Economic Analysis of Hybrid System for Rural Electrification in Cambodia." *Energy Procedia* 138: 524–29.

Lau, K. Y., C. W. Tan, and A. H. M. Yatim. 2015. "Photovoltaic Systems for Malaysian Islands: Effects of Interest Rates, Diesel Prices and Load Sizes." *Energy* 83: 204–16.

MERALCO. n.d. *Rates Archives* [Online]. https://company.meralco.com.ph/news-and-advisories/rates-archives. Accessed February 11, 2020.

National Economic and Development Authority. 2016. *Revisions on ICC Guidelines and Procedures (Updated Social Discount Rate for the Philippines* [Online]. http://www.neda.gov.ph/wp-content/uploads/2017/01/Revisions-on-ICC-Guidelines-and-Procedures-Updated-Social-Discount-Rate-for-the-Philippines.pdf

Ocon, Joey D., and Paul Bertheau. 2019. "Energy Transition from Diesel-Based to Solar Photovoltaics-Battery-Diesel Hybrid System-Based Island Grids in the Philippines—Techno-Economic Potential and Policy Implication on Missionary Electrification." *Journal of Sustainable Development of Energy, Water and Environment Systems* 7 (1): 139–54.

Olatomiwa, Lanre, Richard Blanchard, Saad Mekhilef, and Daniel Akinyele. 2018. "Hybrid Renewable Energy Supply for Rural Healthcare Facilities: An Approach to Quality Healthcare Delivery." *Sustainable Energy Technologies and Assessments* 30 (February): 121–38.

Olatomiwa, Lanre, Saad Mekhilef, and Olayinka S. Ohunakin. 2016. "Hybrid Renewable Power Supply for Rural Health Clinics (RHC) in Six Geo-Political Zones of Nigeria." *Sustainable Energy Technologies and Assessments* 13: 1–12.

Oviroh, Peter Ozaveshe, and Tien Chien Jen. 2018. "The Energy Cost Analysis of Hybrid Systems and Diesel Generators in Powering Selected Base Transceiver Station Locations in Nigeria." *Energies* 11 (3): 7–9.

Panteli, M., C. Pickering, S. Wilkinson, R. Dawson, and P. Mancarella. 2017. "Power System Resilience to Extreme Weather: Fragility Modeling, Probabilistic Impact Assessment, and Adaptation Measures." *IEEE Transactions on Power Systems* 32 (5): 3747–57.

Paterson, Jaclyn, Peter Berr, Kristie Ebi, and Linda Varangu. 2014. "Health Care Facilities Resilient to Climate Change Impacts." *International Journal of Environmental Research and Public Health* 11 (12): 13097–116.

Philippine Statistics Authority. 2020. *Summary Inflation Report Consumer Price Index (2012=100): December 2019* [Online]. http://www.psa.gov.ph/statistics/survey/price/summary-inflation-report-consumer-price-index-2012100-december-2019. Accessed January 22, 2020.

Porcaro, Jem, Sumi Mehta, Matthew Shupler, Sarah Kissel, Michaela Pfeiffer, Carlos Francisco C. Dora, and Heather Adair-Rohan. 2017. *Modern Energy Access and Health* [Online]. https://elibrary.worldbank.org/doi/pdf/10.1596/26648. Accessed November 19, 2019.

Salisu, Sani, Mohd Wazir Mustafa, Olatunji Obalowu Mohammed, Mamunu Mustapha, Touqeer Ahmed Jumani. 2019. "Techno-Economic Feasibility Analysis of an Offgrid Hybrid Energy System for Rural Electrification in Nigeria." *International Journal of Renewable Energy Research* 9 (1): 261–70.

Schaeffer, R., A. S. Szklo, A. F. Pereira de Lucena, B. S. Moreira Cesar Borba, L. P. Pupo Nogueira, F. P. Fleming, A. Troccoli, M. Harrison, and M. S. Boulahya. 2012. "Energy Sector Vulnerability to Climate Change: A Review." *Energy* 38 (1): 1–12.

US AID. 2011. *Power On: Electrification of Rural Health, Education and Tourism Facilities* [Online]. Powering Health: Electrification Options for Rural Health Centers. http://www.poweringhealth.org/Pubs/PNADJ557.pdf. Accessed October 15, 2019.

World Health Organization. 2019. *WHO | Energy Access and Resilience*, WHO. http://www.who.int/sustainable-development/health-sector/health-risks/energy-access/en/. Accessed April 25, 2020.

## Appendix A: Relevant Formulas in HOMER Pro

Annualized Costs

$$C_{annualized} = CRF(i, N) \times C_{NPC,total} = \frac{i(1+i)^N}{(1+i)^N - 1} \times C_{NPC,total}, \tag{A1}$$

where $CRF$ is the capital recovery factor, $i$ the real discount rate, $N$ the total number of years, and $C_{NPC,total}$ the total NPC.

Cost of Energy

$$COE = \frac{C_{annualized}}{E_{served}}, \tag{A2}$$

where $C_{annualized}$ is the annualized cost of the system and $E_{\text{served}}$ the total electrical load served by the system.

Simple Payback Period

$$Simple\ Payback\ Period = \frac{Capital\ Costs_{base} - Capital\ Costs_{alternative}}{Annual\ Costs_{base} - Annual\ Costs_{alternative}}, \tag{A3}$$

Return on Investment (ROI)

$$ROI = \frac{\frac{CNCF_{finalyear} - CNCF_{year0}}{N}}{CNCF_{year0}}, \tag{A4}$$

where $ROI$ is the return on investment, $CNCF$ the cumulative nominal cash flow (at year 0, this is equal to the baseline capital cost less the scenario system capital cost), and $N$ the project lifetime (years).

Internal Rate of Return (IRR)

The internal rate of return is the value of $i$ that would make the following equation equal to zero.

$$\sum_{n=0}^{N} \frac{FV_{base,n}}{(1+i)^n} - \sum_{n=0}^{N} \frac{FV_{alternative,n}}{(1+i)^n} = 0, \tag{A5}$$

where $i$ is the discount rate (IRR, in this case), *base*, *alternative* the base or alternative energy system, $FV$ the future value (difference between cash inflows and outflows), $n$ the year, $N$ the project lifetime (years).

## Appendix B: Computation of the 2019 Solar PV Costs for a 1 kW Commercial System (Adopted From the MS Thesis Manuscript of the Author)

This study assumes that the estimation of the National Renewable Energy Laboratory (NREL) for solar photovoltaic (PV) costs for commercial installation (Fu, Feldman, & Margolis, 2018b) can be used for installations in the Philippines, specifically for the installation of solar PV in rural health units (RHU). Figure B1

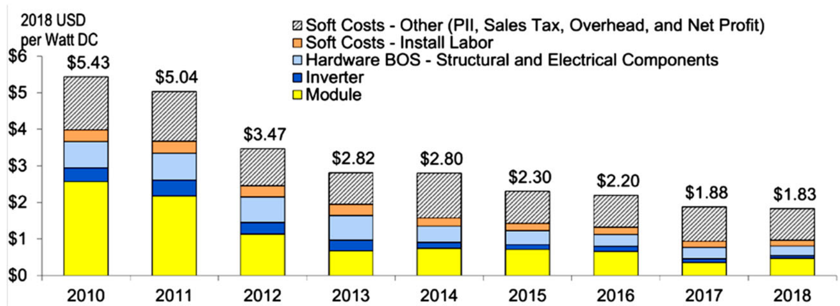



**Figure B1** NREL Commercial PV System Cost Benchmark Summary for 2010–18. *Source*: Fu et al. (2018).

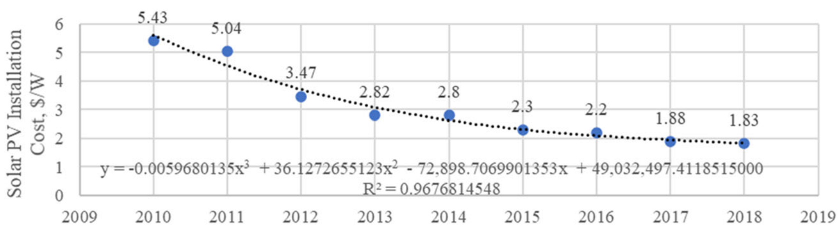



**Figure B2** Plot of NREL 200 kW Commercial PV System Cost for 2010–18.

shows the cost per watt (W), in US dollars (USD) of a 200-kilowatt (kW) commercial PV installation for the years 2010–18.

To predict the 2019 costs, the study used Microsoft Excel to generate a trendline from the plot of PV system costs across the year. This trendline, which assumes a third-order polynomial equation and has an $R^2$ value of 0.9678, is shown in Figure B2. The trendline equation, is as follows, where $y$ is equal to the USD cost per watt and $x$ is the time (year):

$$y = -0.0059680135x^3 + 36.1272655123x^2 - 72,898.7069901353x + 49,032,497.4118515000.$$

Using the generated trendline equation, the 2019 cost of a 200-kW commercial solar PV installation is computed to be 1.4399 USD per W, as shown in Table B1. The table also shows the performance of the regression equation using the mean average percentage error (MAPE) metric.

However, the predicted 2019 cost is applicable only to a 200-kW commercial solar PV installation. Costs are inversely proportional to system size, as Figure B3 shows. This figure illustrates the cost variation among 100-kW, 200-kW, 500-kW, and 1-MW commercial solar PV installations. For this study, the cost of a 1-kW installation was calculated since it is the more appropriate size for the estimated energy consumption profile of the selected RHU.

**Table B1.** NREL Commercial PV System Cost and the Predicted System Cost Per Year

| Year | NREL 2018 USD/W | Predicted USD/W | Percentage Error |
|---|---|---|---|
| 2010 | 5.43 | 5.3618 | 1.26 |
| 2011 | 5.04 | 4.2823 | 15.03 |
| 2012 | 3.47 | 3.4473 | 0.65 |
| 2013 | 2.82 | 2.8210 | 0.04 |
| 2014 | 2.8 | 2.3675 | 15.44 |
| 2015 | 2.3 | 2.0511 | 10.82 |
| 2016 | 2.2 | 1.8360 | 16.55 |
| 2017 | 1.88 | 1.6863 | 10.31 |
| 2018 | 1.83 | 1.5662 | 14.42 |
| | Mean average percentage error (MAPE) | | 9.39 |
| | Predicted 2019 cost (200 kW system) | | 1.4399 USD/W |

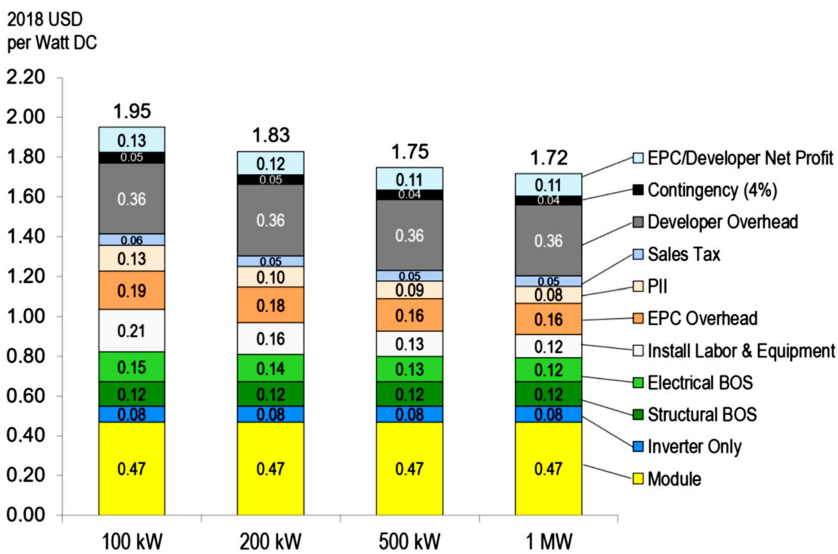



**Figure B3** Q1 2018 U.S. Benchmark: Commercial PV System Cost (2018 USD/W). *Source*: Fu et al. (2018b).

A plot showing the system cost against system size in a logarithmic scale (with 100kW as the base) is shown in Figure B4. The trend of cost with respect to time is assumed to follow a linear distribution. The equation of the trendline, where $y =$ cost and $x =$ system size, is

$$y = -0.45208x + 2.37760.$$

Using the trendline equation, the predicted 2018 cost of a 1-kW system is 2.3776 USD per W. Table B2 shows this value along with the comparison of NREL's reported 2018 costs versus the predicted costs using the trendline equation.

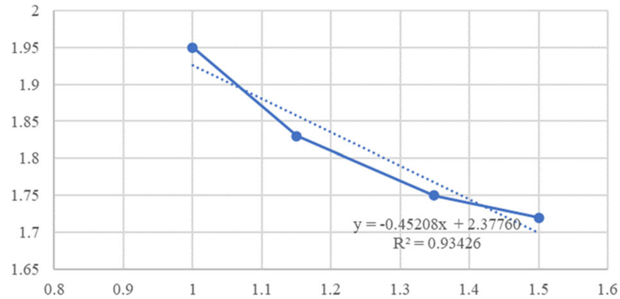



**Figure B4** Plot of Q1 2018 U.S. Benchmark: Commercial PV System Cost (2018 USD/W).

**Table B2.** NREL Commercial PV System Cost and the Predicted Trendline System Cost, According to Capacity Size

| Capacity | NREL 2018 USD/W | Predicted USD/W | Percentage Error |
|---|---|---|---|
| 1,000 kW | 1.72 | 1.6995 | 1.21 |
| 500 kW | 1.75 | 1.7675 | 0.99 |
| 200 kW | 1.83 | 1.8575 | 1.48 |
| 100 kW | 1.95 | 1.9255 | 1.27 |
| | Mean average percentage error (MAPE) | | 1.24 |
| | Predicted 2018 cost (1 kW system) | | 2.3776 USD/W |

The ratio of the price of 1 kW to 200 kW, which is 1.2992, is then used to compute the 2019 cost of a 1 kW commercial solar PV installation. Thus, the 2019 USD/W cost for a 1 kW installation is

$$1.439907\frac{USD}{W} \times 1.2992 = 1.8708\frac{USD}{W}.$$

Thus, the total installation costs of a 1 kW commercial solar PV system in 2019 is USD1,870.78. This is the value used as the input cost of the solar PV component for the simulation. The annual operations and maintenance cost of this system is USD18/kW (Fu et al., 2018b).

## Appendix C: Hourly Load Profile of the Equipment in the Los Baños Rural Health Unit

Tables C1–C5 summarize the observed electricity consumption of each piece of equipment in the Los Baños Rural Health Unit during the weekday. For the weekend profile, the study assumed that only the equipment in the birthing facility is in operation in addition to the refrigerators located in the main building. Some equipment were omitted because they were no longer in use/not observed to be in use.

**Table C1.** Hourly Load Profile of the Equipment in the Los Baños Rural Health Unit

| | | | Hourly Usage | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Equipment | Qty | Watt | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| Lobby | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 8 | 36 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Industrial fan | 1 | 350 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Stand fan 1 | 1 | 65 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Desk fan | 1 | 45 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Computer 1 | 1 | 200 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Computer 2 | 1 | 220 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Printer 1 | 1 | 5 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| MHO office | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 2 | 36 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Aircon 1 | 1 | 660 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Computer 1 | 1 | 200 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Printer 2 | 1 | 8 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Admin office | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 2 | 36 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Aircon 1 | 1 | 660 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Mini fan | 1 | 10 | | | | | | | | | X | X | X | X | X | X | | | | | | | | | | |
| Exhaust fan | 1 | 32 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Computer 2 | 1 | 220 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Computer 2 | 1 | 220 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Printer 1 | 1 | 8 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Printer 2 | 1 | 6.6 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |

*Note*: "X" mark indicates the equipment is in use for that particular hour window.

**Table C2.** Hourly Load Profile of the Equipment in the Los Baños Rural Health Unit (Continuation)

| | | | Hourly Usage | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Equipment | Qty | Watt | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| Pharmacy | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 2 | 36 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Refrigerator | 1 | 435 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Desk fan | 1 | 45 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| ABTC room | | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 2 | 36 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Wall fan 1 | 1 | 45 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Wall fan 1 | 1 | 45 | | | | | | | | | X | X | X | X | X | X | X | X | | | | | | | | |
| Consultation room | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 1 | 36 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Mini fan | 1 | 10 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Wall fan | 1 | 45 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Sanitation room | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 2 | 36 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Stand fan 1 | 1 | 65 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Wall fan | 1 | 45 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Ceiling fan | 1 | 75 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Mini fan | 1 | 10 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Mini fan | 1 | 10 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Computer 2 | 1 | 220 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Computer 2 | 1 | 220 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Printer 2 | 1 | 8 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Typewriter | 1 | 80 | | | | | | | | | X | X | X | X | | X | X | X | X | | | | | | | |
| Hallway | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 4 | 36 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| DOTS | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 2 | 36 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Mini fan | 1 | 10 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Mini fan | 1 | 10 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |

*Note*: "X" mark indicates the equipment is in use for that particular hour window.

**Table C3.** Hourly Load Profile of the Equipment in the Los Baños Rural Health Unit (Continuation)

| Equipment | Qty | Watt | Hourly Usage | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| Laboratory | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 2 | 36 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Lighting 2 | 1 | 12.5 | | | | | | | | | X | X | X | X | X | X | X | X | | | | | | | | |
| Lighting 2 | 1 | 12.5 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Aircon 2 | 1 | 535 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Exhaust fan 2 | 1 | 12 | | | | | | | | | X | X | X | X | X | X | X | X | | | | | | | | |
| Medical refrigerator | 1 | 124 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| LED microscope | 1 | 90 | | | | | | | | | X | X | X | | | | | | | | | | | | | |
| Microscope | 1 | 150 | | | | | | | | | X | X | X | | | | | | | | | | | | | |
| Micro hematocrit centrifuge | 1 | 1386 | | | | | | | | | X | X | X | | | | | | | | | | | | | |
| Centrifuge | 1 | 1400 | | | | | | | | | X | X | X | X | | | | | | | | | | | | |
| Gene expert Machine | 1 | 350 | | | | | | | | | X | X | X | X | X | X | X | | | | | | | | | |
| AVR | 1 | 250 | | | | | | | | | X | X | X | X | X | X | X | X | | | | | | | | |
| Computer 2 | 1 | 220 | | | | | | | | | X | X | X | X | X | X | X | X | | | | | | | | |
| Printer 2 | 1 | 8 | | | | | | | | | X | X | X | X | X | X | X | X | | | | | | | | |
| Dental | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 2 | 36 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Aircon 3 | 1 | 1075 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Exhaust fan 2 | 1 | 12 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Dry heat sterilizer | 1 | 450 | | | | | | | | | | | | | | | X | X | X | | | | | | | |
| UV sterilizer | 1 | 500 | | | | | | | | | | | | | | | | | X | | | | | | | |
| Dental chair | 1 | 374 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Restroom | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 2 | 36 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Stock room | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 2 | 36 | | | | | | | | | X | X | X | X | X | X | X | X | | | | | | | | |
| Water dispenser | 1 | 500 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |

*Note*: "X" mark indicates the equipment is in use for that particular hour window.

**Table C4.** Hourly Load Profile of the Equipment in the Los Baños Rural Health Unit (Continuation)

| | | | Hourly Usage | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Equipment | Qty | Watt | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| Conference room | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 4 | 36 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Aircon 3 | 1 | 1,075 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Aircon 4 | 1 | 720 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Stand fan 1 | 2 | 65 | | | | | | | | | | | | X | | | | | | | | | | | | |
| Refrigerator | 1 | 435 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Gene expert machine | 1 | 350 | | | | | | | | | X | X | X | X | X | X | | | | | | | | | | |
| Biosafety cabinet | 1 | 124 | | | | | | | | | X | X | X | X | X | X | X | | | | | | | | | |
| Computer 2 | 1 | 220 | | | | | | | | | X | X | X | X | X | X | | | | | | | | | | |
| Printer 2 | 1 | 8 | | | | | | | | | X | X | X | X | X | X | | | | | | | | | | |
| Radio | 1 | 7 | | | | | | | | | | | | | X | X | X | X | X | | | | | | | |
| Water dispenser | 1 | 500 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| *Birthing facility* | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lobby | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 32 | 28 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Stand fan | 1 | 65 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Stand fan | 1 | 65 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Computer | 1 | 220 | | | | | | | | | | | | | | | | | | | | | | | | |
| Printer | 1 | 8 | | | | | | | | | | | | | | | | | | | | | | | | |
| TV | 1 | 140 | | | | | | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | |
| Radio | 1 | 12 | X | X | X | X | X | X | X | | X | X | X | X | X | X | | | | | | | | | | X |
| Consultation room | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 2 | 28 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Hall outside CR | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 2 | 1 | 12.5 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Backroom | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 2 | 28 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |

*Note*: "X" mark indicates the equipment is in use for that particular hour window.

**Table C5.** Hourly Load Profile of the Equipment in the Los Baños Rural Health Unit (Continuation)

| | | | Hourly Usage | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Equipment | Qty | Watt | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| Recovery room | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 8 | 28 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Aircon | 1 | 670 | | | | | | | | | | | | X | X | X | X | | | | | | | | | |
| Stand fan | 1 | 65 | | | | | | | | | X | X | X | X | | X | | X | X | | | | | | | |
| Hall—Labor room | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 4 | 28 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Vaccine refrigerator | | 124 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Water dispenser | | 500 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Birthing room | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 6 | 28 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Hospital bed | 1 | 24 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Hospital bed | 1 | 24 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Labor room | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 8 | 28 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Pantry | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 2 | 3 | 12.5 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Social hygiene room | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 4 | 28 | | | | | | | | | | | | | | | X | X | X | | | | | | | |
| Aircon | 1 | 670 | | | | | | | | | | | | | | | X | X | X | | | | | | | |
| Reproductive health room | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 4 | 28 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Aircon | 1 | 670 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Conference room | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 1 | 8 | 28 | | | | | | | | | X | X | X | | | | | | | | | | | | | |
| Aircon | 1 | 670 | | | | | | | | | X | X | X | X | X | X | X | X | X | | | | | | | |
| Outside | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lighting 3 | 3 | 20 | X | X | X | X | X | X | | | | | | | | | | | | | X | X | X | X | X | X |
| Lighting 4 | 4 | 33 | X | X | X | X | X | X | | | | | | | | | | | | | X | X | X | X | X | X |

*Note*: "X" mark indicates the equipment is in use for that particular hour window.

## Appendix D: Results of the Sensitivity Analysis Case With No Birthing Facility Load

In the grid-connected scenario, the optimal configuration consists of 28.67-kW solar PV, the grid, and a 17.53-kW inverter. The optimal configuration's net present cost (NPC) and cost of energy (COE) are lower compared to the base case of a grid-only system. Other parameters are presented in Table D1.

In the off-grid scenario, the optimal configuration consists of 33.63-kW solar PV, 25 units of battery, a 23-kW generator, and a 17.53-kW inverter. The optimal NPC and COE are also lower compared to the base case of a standalone generator. Other parameters are presented in Table D2.

**Table D1.** Comparison of Energy System Configurations for the Grid-Connected Scenario (No Birthing Facility)

| | Architecture | | | | |
|---|---|---|---|---|---|
| Configuration | PV (kW) | 1 kWh LI (units) | Grid (kW) | Inverter (kW) | Dispatch Strategy |
| SPV-G | 28.67 | | 999,999 | 17.53 | Cycle charging |
| SPV-B-G | 28.56 | 1 | 999,999 | 17.44 | Load following |
| G* | | | 999,999 | | Cycle charging |
| B-G | | 1 | 999,999 | 0.18 | Load following |

| | Costs | | | | |
|---|---|---|---|---|---|
| Configuration | NPC (USD) | COE (USD/kWh) | O&M (USD/year) | Initial capital (USD) | System Renewable Fraction (%) |
| SPV-G | 65,724.67 | 0.1154 | 738.03 | 56,796.07 | 73.56 |
| SPV-B-G | 68,501.53 | 0.1206 | 817.24 | 58,614.65 | 73.42 |
| G* | 78,724.26 | 0.1948 | 6,507.26 | 0.00 | 0.00 |
| B-G | 81,564.68 | 0.2018 | 6,570.53 | 2,074.88 | 0.00 |

*Notes*: The grid component was set to 999,999 kW to simulate "infinite" capacity. *, base case; B, battery; G, grid; SPV, solar PV panel.

**Table D2.** Comparison of Energy System Configurations for the Off-Grid Scenario (No Birthing Facility)

| | Architecture | | | | |
|---|---|---|---|---|---|
| Configuration | PV (kW) | 1kWh LI (units) | Generator (kW) | Inverter (kW) | Dispatch Strategy |
| SPV-B-Gen | 33.63 | 25 | 23 | 17.79 | Combined dispatch |
| B-Gen | | 25 | 25 | 7.34 | Cycle charging |
| SPV-Gen | 39.85 | 25 | | 20.14 | Combined dispatch |
| Gen* | | 25 | | | Cycle charging |

| | Costs | | | | System | |
|---|---|---|---|---|---|---|
| Configuration | NPC (USD) | COE (USD/kWh) | O&M (USD/year) | Initial capital (USD) | Renewable Fraction (%) | Fuel (L/year) |
| SPV-B-Gen | 199,737.70 | 0.4942 | 6,747.00 | 118,113.00 | 68.90 | 3,779 |
| B-Gen | 260,915.60 | 0.6456 | 16,822.67 | 57,396.19 | 0.00 | 12,722 |
| SPV-Gen | 378,560.90 | 0.9367 | 24,416.78 | 83,168.59 | 0.00 | 17,490 |
| Gen* | 457,025.90 | 1.1309 | 37,363.93 | 5,000.00 | 0.00 | 28,090 |

*Note*: *, base case; B, battery; G, grid; SPV, solar PV panel.

World Medical and Health Policy



# An Audit of All Waste Leaving the Operating Room: Can the Surgical Suite Be More Environmentally Sustainable?

**Zoe Rammelkamp, Jane Dirnberger, George Johnson, and Steven Waisbren**

*Climate change negatively impacts human health, and yet the healthcare industry is one of the largest generators of waste and greenhouse gas (GHG) emissions. A significant portion of these GHG emissions comes from the production, transport, and disposal of medical equipment, ultimately becoming waste. Within the hospital, about 30 percent of waste is generated in the operating room (OR). The purpose of this study was to determine how much waste was leaving the OR. Two 5-day OR audits at the Minneapolis Veterans Affairs (VA) Health Service found that 231.3 kg of total waste was generated per day, of which 84.5, 8.83, 2.79, and 3.88 percent were general, recyclable, biohazard, and blue wrap waste, respectively. By studying the amounts and types of waste that different hospitals produce, a systems-approach could be applied to waste reduction in the OR and effect policy change that would promote environmental sustainability in the hospital setting.*

**KEY WORDS:** climate change, hospitals, systems, waste reduction, sustainability

## Background

The threat of climate change is becoming increasingly urgent, with the Intergovernmental Panel on Climate Change (IPCC) publishing a report in 2018 that warned the public and policymakers about the environmental consequences of global warming exceeding 1.5°C by 2030 (IPCC, 2018). In the report, the IPCC wrote that in order to limit global warming to 1.5 °C pre-industrial temperatures, we would need rapid and extensive transitions in our industrial systems and infrastructure. The healthcare sector was not excluded from these necessary transitions. As the second-most energy-intensive industry (after the food service), the healthcare sector has an important role to play in reducing its greenhouse gas (GHG) emissions (Crowley, 2016). In fact, the global health services were estimated to be responsible for 4.4 percent of global GHG net emissions, with the United States having the greatest contribution to the global healthcare climate footprint at 7.6 percent (Health Care Without Harm, 2019). One study reported that if the United States' healthcare sector were its own country, it would be the 13th greatest GHG emitter, ahead of the entire United Kingdom (Eckelman & Sherman, 2016). Of note, 71 percent of healthcare's GHG emissions come from the production, disposal, and transport of goods, services, medical equipment, and instruments (Health Care Without Harm, 2019).



doi: 10.1002/wmh3.397

Not only does the US healthcare sector need to change its practices when it comes to promoting environmental sustainability in order to abide by the recommendations of the IPCC, but it also needs to change its practices in order to promote its mission of protecting health and wellbeing. Multiple medical and public health groups have recognized the negative impacts of climate change on human health; the *Lancet* Commission declared that "tackling climate change could be the greatest global health opportunity of the 21st century" (Watts et al., 2016). The World Health Organization (WHO) projects that approximately 250,000 deaths annually between 2030 and 2050 could be attributed to increases in heat exposures in elderly people, as well as increases in diarrheal diseases, vector-borne diseases, flooding, food insecurity, and cardiopulmonary diseases related to air pollution (Haines & Ebi, 2019). There is also some growing concern that when plastic materials are not disposed of properly, they enter the environment as microplastics and cause negative health consequences, including malignancy, neurotoxicity, and autoimmune disorders (Prata et al., 2020).

Thus, systemic change is needed in medical care; health care needs to reduce its consumption of disposable items in order to reduce the GHG emissions it takes to manufacture and dispose of these materials, as well as to reduce the dissemination of microplastics into our environment and into our bodies. One area within the medical field that has been a target for change is the operating room (OR). ORs are estimated to be responsible for approximately 30 percent of the waste generated in the hospital (Thiel et al., 2019). Several studies have performed waste audits that examine how much waste is produced over a period of time in the ORs. Many of these studies, however, focus on specific surgeries, such as total knee arthroplasties (TKAs), otolaryngology procedures, and hysterectomies (Lui, Rudmik, & Randall, 2014; Stall, Yoan Kagoma, & Naudie, 2013; Thiel et al., 2015). One exception is a paper from 2015, which conducted a 1-week prospective waste audit of the operating suite of a 320-bed hospital in Melbourne, Australia (McGain, Jarosz, Nguyen, Bates, & O'Shea, 2015). While this paper provided helpful information about total weights leaving the operating suite, it did not specify which surgeries were producing the waste.

The purpose of the present study is to determine the exact weights and composition of waste generated in the OR setting, broken down by operation, to provide guidance as to which procedures should be the focus of interventions at reducing waste. Furthermore, these data serve as a baseline for future improvements in the Minneapolis VA ORs. Having a baseline will allow the Minneapolis VA to set goals for future waste reduction. We hope to incorporate interventions to make the OR a more environmentally sustainable part of the hospital, and we hope to encourage other institutions to determine what their baseline amount of OR waste is and to be motivated to make changes to their OR practices.

## Materials and Methods

For 5 days in September of 2019, from 9:00 a.m. until 5:00 p.m., all waste coming out of the 23-bed OR suite and into the waste room was measured in pounds according to whether it was general, recyclable, biohazard, and blue wrap waste. This audit took place at the Minneapolis VA Medical Center, which is a 390-bed tertiary care center in Minneapolis, MN. A portable, standing scale, accurate to 0.1 lbs, was used to measure bags of waste. A single volunteer was recruited to record the weights of these bags. This volunteer wore scrubs and gloves while taking all measurements. Additionally, no patient-identifiable information was collected during this quality improvement audit, which was exempt from IRB review. These same data were recorded for 5 days 2 months later in December 2019 using the same scale and volunteer. Waste from operations that took place before 9:00 a.m. or after 5:00 p.m. was not measured.

Between the September and December audits, a brief presentation was given to the OR staff during their weekly meeting. This talk took place in the middle of November and lasted about 10 minutes. The presentation included PowerPoint slides with the results of the waste audit from September. During this presentation, OR staff were encouraged to practice proper waste segregation practices and were invited to ask questions. There were about 20 OR staff members present at this meeting and no questions were asked about the audit. One staff member asked to have a refresher course on which items can be recycled and which must be thrown into general waste. Plans were made to provide this refresher course after getting updated information from the Waste Management Department.

At the time of this audit, general trash consisted of soft plastics, tubing, used laparotomy pads, disposable gowns, and anything that had slight traces of bodily fluids or chemicals. Recyclable waste included hard plastics, cardboard, and glass bottles. Biohazard waste was waste that left the OR suite in a red bag; it generally consisted of bottles of urine, blood products, and any material that was dripping with bodily fluids or chemicals. Blue wrap, which is a No. 5 plastic composed of polypropylene used to wrap instruments and kits for sterilization (Albert & Rothkopf, 2015), was measured separately and sent to an outside facility to be recycled there. Of note, that facility would not accept any contaminated blue wrap, so any blue wrap that became contaminated had to go into general waste. Sharps were not measured in this audit. Additionally, a Neptune Waste Management System was used during many of the operations performed at the Minneapolis VA to suction excess bodily fluids, but the volumes of these fluids were not able to be recorded for every operation. Therefore, the volume of bodily fluids collected from the Neptune is not included in this waste audit.

All data were sorted and analyzed using 2013 Microsoft Excel. Data were converted from pounds to kilograms during the analysis.

## Results

The mean number of operations per day during the first 5-day audit in September 2019 was 30, but only 27 took place between the hours of 9:00 a.m. through 5:00 p.m. This was similar to the number of operations during the 5-day audit in December 2019, with a mean of 31 operations per day with 29 completed between the hours of 9:00 a.m. through 5:00 p.m. An inventory of all operations that were performed more than once is listed in Table 1 according to how much general, recyclable, biohazard, blue wrap, and total waste they produced on mean. The number of times these operations took place over the combined 10-day audit is also included and recorded in Table 1. Operations that only took place once over the audit are not included in Table 1.

Mean total of 231.3 kg of waste per day was produced during these two 5-day audits; general waste made up 195.4 kg (84.49 percent), compared with 20.4 kg (8.83 percent) of recyclable waste, 16 kg (2.8 percent) of biohazard waste, and 9.0 kg (3.9 percent) of blue wrap waste. A comparison between the 5-day audits in September and December did not show a meaningful difference in the amount of waste generated (Figure 1). As demonstrated in Figure 2, the vast majority of the waste generated in the OR was disposed of in the general trash bins and was not recycled.

This audit revealed that at the Minneapolis VA, coronary artery replacement graft (CABG) operations produce the most trash per operation with a mean of 32.7 kg of total waste. However, the procedures that were performed the most often were cataract operations and TKAs. A total of 50 cataract operations were performed during these two 5-day audits, with a mean of 4.7 kg being produced per cataract operation, 75 percent of which was general waste. Fourteen TKAs were performed over the combined 10 days, with a mean of 15.6 kg being produced per TKA, 82.4 percent of which was general waste. When the sum of the three CABGs was added together, a mean total of 98.0 kg of waste was produced (80 percent general waste). In comparison, the sum of all TKAs from the combined 10-day audit equaled 218.5 kg. For cataract operations, the mean total waste was greatest over the 10 days, with a total of 233.6 kg of waste. Thus, the cataract operations contributed the most to the overall amount of waste leaving the surgical suite over this 10-day audit, followed by TKAs and then CABGs. These are the three operations that would be most appropriate to target for future changes in OR practices.

When comparing the September and December audits, there was no major difference. The only intervention that took place between those two audits was a brief presentation detailing the results of the September audit to the OR staff.

## Discussion

Performing a waste audit of the OR suite is the first step to identifying areas for improvement in greening OR practices because it provides a baseline for hospitals to set waste-reduction goals. While it is possible to compare OR waste production between institutions by simply measuring the amount of waste that leaves the hospital to go to the incinerator or landfill, it is important to compare the case composition of each of the hospitals. As demonstrated in this study, less complex cases, such as cataract operations, generate less waste compared to more complex procedures, such as cardiac bypass graphing. Thus, comparisons would need to be made comparing similar procedures, not overall waste production.

Nevertheless, it is useful to consider the composition of overall waste produced between hospitals. Only 45 percent of waste was general waste in the study in Melbourne, although biohazard waste made up 32 percent of the waste there, for a

**Table 1.** An Inventory of All Operations

| Procedure (*n*) | Waste (%) | Recycling (%) | Biohazard (%) | Blue wrap (%) | Total weight (kg) |
|---|---|---|---|---|---|
| CABG (3) | 26.1 (80.2) | 2.9 (8.7) | 1.9 (5.9) | 1.7 (5.2) | 32.7 |
| TAVR (2) | 23.2 (90.1) | 2.2 (8.5) | 0.1 (0.4) | 0.1 (0.5) | 25.6 |
| Laparoscopic prostatectomy (2) | 19.8 (88.4) | 1.3 (5.7) | 0.9 (4) | 0.5 (2) | 22.4 |
| Aneurysm repair (2) | 19.1 (90.3) | 1.2 (5.8) | 0.6 (3.0) | 0.2 (0.9) | 21.1 |
| Laparoscopic bowel resection (4) | 16.4 (87.0) | 1.8 (9.4) | 0.0 (0.0) | 0.7 (4) | 18.9 |
| Laparoscopic gastric bypass (2) | 12.6 (66.8) | 1.9 (10) | 3.4 (18) | 1.0 (5.3) | 18.9 |
| VATS lobectomy (3) | 13.3 (81.4) | 1.8 (11) | 0.0 (0.0) | 1.3 (7.8) | 16.4 |
| TKA (14) | 12.9 (82.4) | 1.5 (9.4) | 0.5 (3) | 0.8 (5.0) | 15.6 |
| Hip arthroplasty (3) | 11.5 (83.3) | 1.3 (9.5) | 0.0 (0.0) | 1.0 (7.2) | 13.8 |
| Guillotine amputation (2) | 11.2 (87.9) | 1.3 (10) | 0.2 (1) | 0.1 (0.7) | 12.7 |
| Angiogram (3) | 11.9 (93.6) | 0.8 (6) | 0.0 (0.0) | 0.0 (0.0) | 12.7 |
| TSA (6) | 11.0 (86.8) | 1.4 (11) | 0.0 (0.0) | 0.3 (2) | 12.7 |
| Laparoscopic sleeve gastrectomy (3) | 8.7 (73) | 1.8 (15) | 0.8 (7) | 0.6 (5) | 12.0 |
| TCAR (3) | 10.1 (89.9) | 0.9 (8) | 0.2 (2) | 0.0 (0.0) | 11.2 |
| Laminectomy (6) | 10.4 (94.4) | 0.5 (4) | 0.1 (0.8) | 0.0 (0.6) | 11.0 |
| Laparoscopic hernia repair (5) | 9.1 (88) | 0.9 (8) | 0.0 (0.0) | 0.3 (3) | 10.3 |
| I&D (6) | 9.3 (92) | 0.4 (4) | 0.0 (0.0) | 0.4 (4) | 10.0 |
| Orchiectomy (2) | 7.7 (79) | 0.5 (6) | 0.5 (5) | 1.0 (11) | 9.8 |
| Penile implant (3) | 7.5 (79) | 1.4 (15) | 0.3 (3) | 0.2 (2) | 9.4 |
| Mouth excision (2) | 7.0 (76) | 0.8 (9) | 1.3 (14) | 0.0 (0.0) | 9.2 |
| Skin lesion excision (2) | 8.0 (91) | 0.5 (6) | 0.0 (0.0) | 0.3 (3) | 8.7 |
| BKA (2) | 7.4 (86) | 0.5 (5) | 0.0 (0.0) | 0.7 (8.5) | 8.6 |
| Cystoscopy + procedure (6) | 6.7 (88) | 0.3 (5) | 0.2 (3) | 0.4 (5) | 7.6 |
| Open hernia repair (11) | 6.7 (89) | 0.6 (8) | 0.2 (2) | 0.0 (0.0) | 7.5 |
| Mandible repair (3) | 6.1 (80) | 0.3 (4) | 1.1 (15) | 0.0 (0.0) | 7.5 |
| Fistulotomy (2) | 6.6 (88) | 0.3 (4) | 0.5 (7) | 0.0 (0.0) | 7.5 |
| Exam under anesthesia (4) | 6.0 (87) | 0.5 (7) | 0.4 (6) | 0.0 (0.0) | 6.9 |
| RFA (2) | 5.3 (78) | 0.6 (9) | 0.0 (0.0) | 0.9 (14) | 6.7 |
| TURBT (4) | 6.1 (91) | 0.2 (3) | 0.0 (0.0) | 0.4 (6) | 6.7 |
| URS (8) | 6.0 (91) | 0.2 (3) | 0.0 (0.0) | 0.4 (6) | 6.6 |
| Deep brain stimulation (2) | 5.8 (91) | 0.6 (9) | 0.0 (0.0) | 0.0 (0.0) | 6.4 |
| Biopsy of penile mass (2) | 5.8 (93) | 0.4 (6) | 0.0 (0.0) | 0.0 (0.0) | 6.2 |
| Debridement of foot (3) | 5.9 (95) | 0.3 (5) | 0.0 (0.0) | 0.0 (0.0) | 6.2 |
| Gastrocnemius repair (2) | 5.5 (91) | 0.5 (8) | 0.0 (0.0) | 0.0 (0.0) | 6.0 |
| Sural nerve biopsy (2) | 5.8 (96) | 0.2 (3) | 0.0 (0.0) | 0.0 (0.0) | 5.9 |
| TURP (3) | 4.3 (73) | 1.0 (16) | 0.0 (0.0) | 0.7 (11) | 5.9 |
| Cataract surgery (50) | 3.5 (75) | 0.9 (19) | 0.0 (0.0) | 0.3 (6) | 4.7 |
| Misc. IR procedures (2) | 4.6 (100) | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.0) | 4.6 |
| Microscopic laryngoscopy (3) | 3.6 (79) | 0.4 (9) | 0.5 (12) | 0.0 (0.0) | 4.6 |
| Vasectomy (2) | 3.5 (78) | 0.5 (10) | 0.0 (0.0) | 0.6 (13) | 4.5 |
| Carpal tunnel release (2) | 3.2 (79) | 0.3 (6) | 0.0 (0.0) | 0.6 (15) | 4.1 |
| Cystoscopy (29) | 1.5 (82) | 0.1 (5) | 0.0 (0.0) | 0.2 (14) | 1.8 |

*Note*: Weight in kilograms is listed for each type of waste. The percentage of the total weight is listed in parentheses next to the weight. BKA, below-knee amputation; CABG, coronary artery bypass graft; I&D, incision and drainage; IR, interventional radiology; RFA, radiofrequency ablation; TAVR, transcatheter aortic valve replacement; TCAR, transcarotid artery revascularization; TKA, total knee arthroplasty; TSA, total shoulder arthroplasty; TURBT, transurethral resection of bladder tumor; TURP, transurethral resection of the prostate; URS, ureteroscopy; VATS lobectomy, video-assisted thoracoscopic lobectomy.

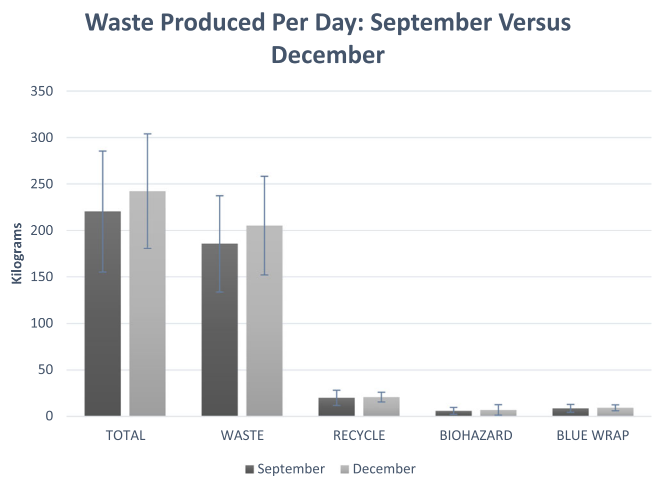



**Figure 1** A Comparison of the Mean Weights of Waste Produced Each Day in the Operating Room (September vs. December). There was no significant difference.

total of 77 percent nonrecyclable waste. In Minneapolis, for a total of 88 percent nonrecyclable waste, approximately 85 percent of the waste was general waste and 3 percent was biohazard waste. The recycling rate in Melbourne was 23 percent, compared with 13 percent in Minneapolis (blue wrap plus recyclable waste). Other studies have suggested that recycling rates of 40 percent can be achieved at some hospitals (Stall et al., 2013).

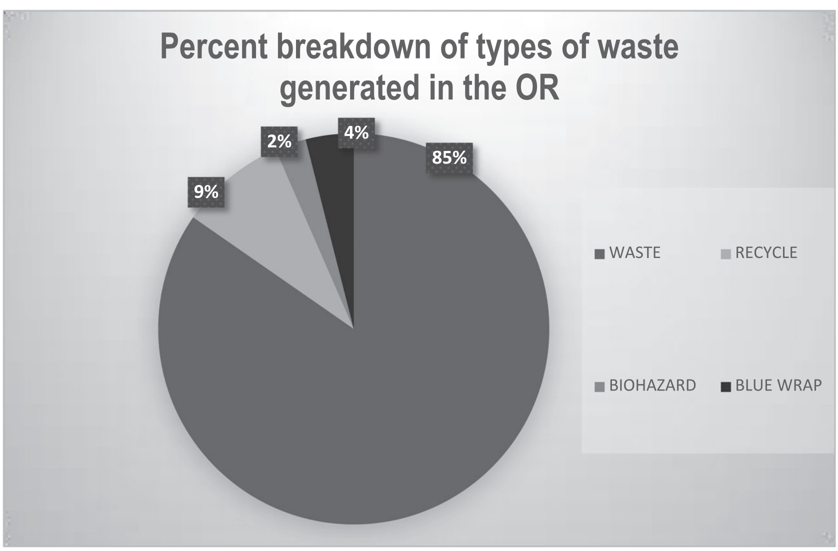



**Figure 2** 85 Percent of Waste was General Waste, 9 Percent Was Recyclable Waste, 4 Percent Was Blue Wrap Waste, and 2 Percent Was Biohazard Waste. OR, operating room.

Next, when separating the TKAs performed at the Minneapolis VA and comparing the waste from those operations to the waste studied in a 2013 waste audit in Canada that looked specifically at TKAs, the Minneapolis VA appeared to produce relatively equivalent numbers. The Canadian study found the mean total weight of a TKA to be 13.3 kg, while the audit at the Minneapolis VA found the mean total waste to be 15.6 kg per TKA. The combined recycling rate of blue wrap and recyclables for TKAs was similar at both institutions, with 14.3 percent in Canada compared with 14.4 percent at the Minneapolis VA.

Despite potential differences in case volumes and cultures between hospitals, we still can learn from each other. For instance, Western Hospital in Melbourne uses reusable cloth drapes and gowns while the Minneapolis VA uses disposables. This could certainly account for some of the differences in waste profiles between the two institutions. We recognize that Minneapolis, Canada, and Australia are in geographically distant parts of the world, but being able to compare the waste at these different hospitals and taking note of which hospitals have better recycling rates can inspire change and provide strategies for minimizing waste in the OR.

Other strategies that could be implemented at the Minneapolis VA that have been utilized in other hospitals include limiting the use of disposable packs, especially the use of disposable cotton towels, which have a large carbon footprint compared to reusable cloth materials (Campion et al., 2015). In general, reusable equipment, such as reusable isolation gowns, has been shown to be safe and to be more environmentally friendly compared to their disposable counterparts (Vozzola, Overcash, & Griffing, 2018). Similarly, when studying life cycle assessments on single-use laryngoscopes versus reusable ones, it was found that reprocessing the reusable ones actually produced less GHG emissions, despite the fact that they had to be disinfected and sterilized (Sherman, Lewis, & Matthew, 2018). We can conclude from these studies that reusing items is safe, cost-effective, and more environmentally friendly compared to using single-use items. Of note, the Joint Commission International discourages reprocessing surgical materials because of extreme caution over the safety of this strategy (Mansur, 2017).

Reducing pharmaceutical waste is another strategy that could have both environmental and cost-saving benefits to the hospital, especially in cataract correction procedures, where 43 percent of pharmaceutical waste is estimated to be wasted (Tauber et al., 2019). Modifying surgical kits by minimizing the number of unnecessary items in the custom packs, as was done at the University of Pittsburgh Medical Center, is another way to reduce waste in the OR. In that study, the items that were thought to be unnecessary or redundant were eliminated from the standard hand surgery custom pack, resulting in about 13 percent less surgical waste per case (Thiel et al., 2019).

The general surgery department at the Minneapolis VA has also noticed redundancy in the packaging of OR supplies. For instance, some hernia meshes are packaged in individual cardboard boxes four to five times the size of the mesh, while other suppliers of similar meshes use thin individual packaging that results in much less waste. The environmental footprint of these products is not taken into consideration with purchasing decisions. Therefore, even though the Minneapolis VA is a leader in environmental sustainability within the VA healthcare system, there are several strategies that the Minneapolis VA can employ to improve its waste and carbon footprint. Other hospitals should be encouraged to apply these strategies in their own ORs.

It is also worthwhile to note that between September and December, there was no meaningful difference between the amount of waste or the composition of waste generated during those two audits. This lack of change shows that the educational intervention that took place in the middle of November did not have an impact on reducing waste or increasing recycling. This finding is not unexpected; the presentation delivered to the OR staff at that time was very brief and many people were not in attendance.

This expected finding supports the known fact that education and knowledge about recycling is an important driver in recycling behaviors (Whitmarsh, Haggar, & Thomas, 2018). At the Minneapolis VA, one of the Assistant Nurse Managers has been a leader in educating OR staff about waste segregation. From 2016 to 2017, there was a large campaign to educate OR staff about proper waste disposal, which consisted of presentations at all-staff meetings. Anesthesia and nursing staff were present at these meetings; surgeons were not included because they do not dispose of garbage as they are scrubbed in during the procedures. These presentations ended with a quiz that tested staff on which items go into which waste stream (recycle, general waste, hazardous).

As new staff has been hired since 2017, it would be important to resume that recycling campaign. Additionally, because behavior change is a process that takes place over time, frequent education about recycling procedures would benefit all staff, not just new employees. The COVID-19 pandemic has slowed down these training programs as well as other sustainability initiatives at the Minneapolis VA, but we recognize the need for both systems changes and behavior changes in order to facilitate a more sustainable healthcare sector (Grose, Bennallick, Nichols, Pahl, & Richardson, 2012).

## Conclusions and Policy Implications

Since 71 percent of healthcare's climate footprint is estimated to be derived from the use of medical equipment itself, tackling the problem of OR waste is of paramount importance. An important first step in combatting waste in the hospital setting is to conduct an audit that identifies problematic areas. We encourage other hospitals to perform their own audits and to share their efforts at waste reduction so that we may all benefit. If hospitals can perform waste audits that carefully document how much waste is being produced, then they will have more leverage when advocating for policies that will make their hospitals more environmentally sustainable.

Of note, VA Directive 7348, published in March 2012, prohibits the repurposing or donation of any unrequired or excess materials. Some private and university hospitals have been able to mitigate their waste profiles by donating unused, expired, or excess equipment to third-world institutions, but per VA policy, this is not allowed. Additionally, it is against VA policy to use repurposed surgical equipment.

As the VA system is the largest healthcare provider in the United States, changing these policies could provide a huge opportunity for improvement in environmental sustainability within the healthcare system.

It is ironic that the healthcare sector is such a large contributor to climate change and plastic waste, as we know that climate change and environmental contaminants negatively impact human health. New policies and practices need to be adopted in the United States to protect both the health of this planet and the health of our patients. Such policy changes would include mandating manufacturers to reduce packaging so that there is less waste, revising VA policy that prohibits the donation and repurposing of equipment, requiring hospitals to take into consideration the carbon footprint of materials when they are purchasing goods, permitting the reuse of pharmaceuticals for multiple patients, and switching to reusable gowns and drapes throughout the hospital.

Finally, we need rapid innovation in technology and material science; we would encourage policymakers to provide funding and research for the development of biodegradable materials. It is also important to note that in the United States, we do not have the infrastructure to recycle plastic waste; the 2013 Chinese Green Fence campaign, which restricted waste coming into China from other nations, revealed this unfortunate truth (Brooks, Shuli Wang, & Jambeck, 2018). Therefore, we also need policies that will promote better recycling infrastructure here in the United States.

## Limitations and Bias

Limitations of this study include daily time restraints; not all waste could be weighed because the conclusion of the operation took place outside of the allotted time slot. Therefore, there were some missed data. Additionally, the procedures that took place only once were not included in Table 1 as it would be difficult to extrapolate the accuracy of those measurements without additional data. Furthermore, the specific surgeons and nurses present during the operations were not recorded, so there could be some variability in waste based on the personal techniques and practices of the staff present during the procedure.

**Zoe Rammelkamp** is a third-year internal medicine resident at the University of Minnesota and will be working as a primary care physician after she graduates.

**Jane Dirnberger** was previously the Assistant Nurse Manager of the Operating Room at the Minneapolis VA Medical Center and is currently working in the Quality, Value and Safety department.

**George Johnson** is the Sustainability and Environmental Compliance Program Manager at the Minneapolis VA Medical Center, where he promotes energy and water conservation, recycling, and waste reduction in all areas of the hospital.

**Steven Waisbren** holds a Ph.D. in cellular and molecular physiology and is a staff surgeon/assistant service chief in general surgery at the Minneapolis VA Medical Center and an assistant professor in surgery at the University of Minnesota.

## Notes

Conflicts of interest: None declared.

**Corresponding author**: Zoe Rammelkamp, ramme007@umn.edu

## References

Albert, Mark, and Douglas Rothkopf. 2015. "Operating Room Waste Reduction in Plastic and Hand Surgery." *Plastic Surgery* 23 (4): 235–238, https://doi.org/10.4172/plastic-surgery.1000941

Brooks, Amy L., Shuli Wang, and Jenna R. Jambeck. 2018. "The Chinese Import Ban and Its Impact on Global Plastic Waste Trade." *Science Advances* 4: eaat0131, https://doi.org/10.1126/sciadv.aat0131

Campion, Nicole, Cassandra Thiel, Noe Woods, Swanzy L. Leah, Amy Landis, and Melissa Bilec. 2015. "Sustainable Healthcare and Environmental Life-Cycle Impacts of Disposable Supplies: A Focus on Disposable Custom Packs." *Journal of Cleaner Production* 94: 46–55, https://doi.org/10.1016/j.jclepro.2015.01.076

Crowley, Ryan. 2016. "Climate Change and Health: A Position Paper of the American College of Physicians." *Annals of Internal Medicine* 164: 608–610, https://doi.org/10.7326/M15-2766

Eckelman, Matthew, and Jodi Sherman. 2016. "Environmental Impacts of the US Health Care System and Effects on Public Health." *PloS ONE* 11 (6): e0157014, https://doi.org/10.1371/journal.pone.057014

Grose, Jane, Maria Bennallick, Andrew Nichols, Sabine Pahl, and Janet Richardson. 2012. "Facilitating Sustainable Waste Management Behaviors Within the Health Sector: A Case Study of the National Health Service (NHS) in Southwest England, UK." *Sustainability* 4 (4): 630–642, https://doi.org/10.3390/su4040630

Haines, Andy, and Kristie Ebi. 2019. "The Imperative for Climate Action to Protect Health." *New England Journal of Medicine* 380 (3): 263–73, https://doi.org/10.1056/NEJMra1807873

Health Care Without Harm. 2019. *Health Care's Climate Footprint* [Online]. https://noharm-global.org/sites/default/files/documents-files/5961/HealthCaresClimateFootprint_092319.pdf. Accessed November 18, 2019.

Intergovernmental Panel on Climate Change (IPCC). 2018. "Summary for Policymakers." In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty, eds. Masson-Delmotte, Valerie, Panmao Zhai, Hans-Otto Pörtner, Debra Roberts, James Skea, Priyadarshi Shukla, Anna Pirani, Wilfran Moufouma-Okia, Clotilde Péan, Roz Pidcock, Sarah Connors, J.B. Robin Matthews, Yang Chen, Xueping Zhou, Melissa Gomis, Elizabeth Lonnoy, Thomas Maycock, Melinda Tignor, and Tim Waterfield. Geneva: World Meteorological Organization, 32. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf

Lui, Justin, Luke Rudmik, and Derrick Randall. 2014. "Reducing the Preoperative Ecological Footprint in Otolaryngology." *Otolaryngology-Head and Neck Surgery* 151 (5): 805–810, https://doi.org/10.1177/0194599014544449

Mansur, Jeannell M.2017. "Reuse of Single-Use Devices: Understanding Risks and Strategies for Decision-Making for Health Care Organizations." Joint Commission International. https://www.jointcommissioninternational.org/-/media/feature/news/jci_white_paper_reuse_of_single_use_devices2pdf.pdf?db=web&hash=6A41E61718E881E936AF4289BE36DA82

McGain, Forbes, Katherine Jarosz, Martin Nguyen, Samantha Bates, and Catherine O'Shea. 2015. "Auditing Operating Room Recycling: A Management Case Report." *International Anesthesia Research Society* 5 (3): 47–50, https://doi.org/10.1213/XAA.0000000000000097

Prata, Joana Correia, João P. da Costa, Isabel Lopes, Amando C. Duarte, and Teresa Rocha-Santos. 2019. "Environmental Exposure to Microplastics: An Overview on Possible Human Health Effects." *Science of Total Environment* 702 (2020) 13445, https://doi.org/10.1016/j.scitotenv.2019.134455

Sherman, Jodi D., A. Rabley Lewis, IV, and J. Eckelman Matthew. 2018. "Life Cycle Assessment and Costing Methods for Device Procurement: Comparing Reusable and Single-Use Disposable Laryngoscopes." *Anesthesia & Analgesia* 127 (2): 434–443, https://doi.org/10.1213/ANE.0000000000002683

Stall, Nathan, Jennifer Bondy Yoan Kagoma, and Douglas Naudie. 2013. "Surgical Waste Audit of 5 Total Knee Arthroplasties." *Canadian Journal of Surgery* 56 (2): 97–102, https://doi.org/10.1503/cjs.015711

Tauber, Jenna, Ijeoma Chinwuba, David Kleyn, Michael Rothschild, Jonathan Kahn, and Cassandra Thiel. 2019. "Quantification of the Cost and Potential Environmental Effects of Unused Pharmaceutical Products in Cataract Surgery." *JAMA Ophthalmology* 137 (10): 1156–1163, https://doi.org/10.1001/jamaophthalmol.2019.2901

Thiel, Cassandra, Rafaela Fiorin Carvalho, Lindsay Hess, Joelle Tighe, Vincent Laurence, Melissa Bilec, and Mark Baratz. 2019. "Minimal Custom Pack Design and Wide-Awake Hand Surgery: Reducing Waste and Spending in the Orthopedic Operating Room." *Hand* 14 (2): 271–276, https://doi.org/10.1177/1558944717743595

Thiel, Cassandra, Matthew Eckelman, Richard Guido, Matthew Huddleston, Amy Landis, Scott Shrake JodiSherman, Noe Copley-Woods, and Melissa Bilec. 2015. "Environmental Impact of Surgical Procedures: Life Cycle Assessment of Hysterectomy in the United States." *Environmental Science & Technology* 49: 1779–1786, https://doi.org/10.1021/es504719g

Vozzola, Eric, Michael Overcash, and Evan Griffing. 2018. "Environmental Considerations in the Selection of Isolation Gowns: A Life Cycle Assessment of Reusable and Disposable Alternatives." *American Journal of Infection Control* 46: 881–886, https://doi.org/10.1016/j.ajic.2018.02.002

Watts, Nick, W Neil Adger, Sonja Ayeb-Karlsson, Yuqi Bai, Peter Pyass, Diarmid Campbell-Lendrum, Tim Colbourn et al. 2016. "The *Lancet* Countdown: Tracking Progress on Health and Climate Change." www.thelancet.com. https://doi.org/10.1016/S0140-6736(16)32124-9

Whitmarsh, Lorraine E., Paul Haggar, and Merryn Thomas. 2018. "Waste Reduction Behaviors at Home, at Work, and on Holiday: What Influences Behavioral Consistency Across Contexts?" *Frontiers in Psychology* 9 (2447): 1–13, https://doi.org/10.3389/fpsyg.2018.02447

World Medical and Health Policy



# Health Professionals and the Climate Crisis: Trusted Voices, Essential Roles

**Edward Maibach, Howard Frumkin, and Samantha Ahdoot**

*Climate change has triggered a global public health emergency that, unless adequately addressed, is likely to become a multigenerational public health catastrophe. The policy actions needed to limit global warming deliver a wide range of public health benefits above and beyond those that will result from limiting climate change. Moreover, these health benefits are immediate and local, addressing one of the most vexing challenges of climate solutions: that the benefits of greenhouse gas reduction are seen as long-term and global, which are remote from the concerns of many jurisdictions. In this commentary, we identify roles that health professionals and health organizations can play, individually and collectively, to advance equitable climate and health policies in their communities, health systems, states, and nations. Ultimately, health voices can work across national boundaries to influence the world's commitments to the Paris Agreement, arguably the world's most important public health goal.*

**KEY WORDS:** climate change, global health, public health, advocacy, public policy

## Introduction

A stable climate is arguably the most fundamental determinant of human health (McMichael, 2017). Earth's climate, however, is currently changing at an unprecedented rate (World Meteorologic Organization, 2019). This rapid climate change has triggered a global public health emergency that, unless adequately addressed, is likely to become a sustained public health catastrophe that will last many generations (IPCC, 2018; Harmer, 2020).

Serious direct health harms of climate change result from increasingly extreme weather—including more frequent and severe heatwaves, storms, floods, and droughts. Indirect health harms resulting from secondary consequences of climate change are even more insidious—air pollution, vector-borne illness, contaminated water and food, crop and livestock loss and reduced nutrient value, damaged and destroyed housing and farmlands, mental health impacts, and increases in conflict and forced migration. All of these impacts are magnified by socioeconomic and





doi: 10.1002/wmh3.421

biological factors—including age, gender, poverty and income inequality, underlying health problems, racism, and discrimination—such that the health of more vulnerable, marginalized, and disempowered people tends to be harmed first and worst (Ebi et al., 2018; Watts et al., 2015).

Currently, the world's stated goal—as ratified in the Paris Climate Agreement in 2015—is to limit global warming to no more than 2°C. Subsequently, however, the Intergovernmental Panel on Climate Change has warned that warming of 2°C should not be considered safe; they suggested 1.5° as a more prudent global goal (IPCC, 2018). Regrettably, global efforts to date are falling far short of what is necessary to limit the warming to 2°, much less 1.5°, with models currently projecting 3° of warming as a more likely outcome (Watts et al., 2020). Planetary health rescue will require far-reaching transformations across the global economy; while many of the needed technologies are now available, neither effective political leadership nor widespread public buy-in has yet emerged.

## A Focus on Health May Help Untie the Gordian Knot

There is a bright silver lining to this dire situation. The policy actions that are most needed to limit global warming to levels that could be considered safe for public health and wellbeing also deliver a wide range of additional public health benefits above and beyond those that will result from limiting climate change. In a very real sense, climate solutions are health solutions.

Many of the public health benefits of climate policies begin accruing almost immediately upon implementing the policy actions. Furthermore, the primary beneficiaries of these policy actions are the people in the jurisdictions that implement them. In other words, the health benefits of climate solutions are proximal in both time and space. This helps to solve one of the most vexing challenges associated with climate solutions—that their climate change benefits accrue primarily in the distant future, and are globally distributed, undermining many jurisdictions' willingness to undertake them.

The decarbonization of electrical and transportation systems provides a useful example. Although these are actions that must soon be taken worldwide in order to achieve the goal of the Paris Agreement, any city, or state, or nation that shifts to renewable electricity will immediately realize benefits from cleaner air and water, healthier people, and reduced health costs. Moreover, these transitions are employment-intensive (Georgeson & Maslin, 2019). The jobs and other forms of economic prosperity that are created will also further enhance public health and wellbeing in that jurisdiction because secure employment and economic prosperity are important social determinants of health.

The U.S. state of Wisconsin provides an excellent example. A University of Wisconsin research team modeled the health and economic impacts that would accrue if the state meets 100 percent of its energy needs with clean energy (e.g., wind, solar) produced in-state (Abel & Spear, 2019). Achieving that goal would create 161,100 net jobs (more than doubling the current number of energy jobs in the state), increase state GDP by nearly 5 percent, increase state tax revenue by more than $500 M per year, and avoid human health damages that cost more than $21B annually.

In addition to the rapid decarbonization of energy and transportation systems, a wide variety of other policies that are necessary to achieve the goal of limiting global warming to 2°C or less will also deliver short- and long-term health benefits. These include improving food systems, the built environment, land-use practices, access to family planning services, and education of women and girls. These benefits have been described in detail, and in most cases quantified (Gao et al., 2018; Milner et al., 2020; Shindell, Faluvegi, Seltzer, & Shindell, 2018).

## Health Professionals Can Play Many Important Roles

Another silver lining to the climate crisis is that physicians and other health professionals increasingly understand the human health relevance of climate change (Hathaway & Maibach, 2018). In large numbers, they believe the organizations that represent them should engage in both public and policymaker education about the climate crisis, as well as in advocacy to ensure that appropriate policy measures are adopted to protect health (Kotcher et al., 2021; Sarfaty, Mitchell, Bloodhart, & Maibach, 2014; Sarfaty et al., 2015; Sarfaty, Kreslake, Casale, & Maibach, 2016).

Research shows that physicians and other health professionals are highly trusted sources of information around the world (Chen, Vasudev, Szeto, & Cheung, 2018; Clemence, 2020; Reinhart, 2020; Ipsos, 2019), and that presenting information about the health harms of climate change is an effective communication strategy that leads to enhanced issue engagement (Maibach, Sarfaty, Mitchell, & Gould, 2019). Moreover, many health professionals are personally inclined to get involved in relevant education and advocacy activities (Hubbert, Ahmed, Kotcher, Maibach, & Sarfaty, 2020; Kotcher et al., 2021; Sarfaty et al., 2014, 2015).

Every physician and nurse fulfills multiple roles—as a family member, a community member, a professional, and a citizen. Grounded in these roles, they can, and we argue should help achieve the goal of limiting global warming to no more than 2°C.

At the most basic level, change begins at home. Health professionals can take steps to decarbonize their own personal lives, for example by powering their homes with clean energy (e.g., solar), reducing their home energy use (e.g., heat pumps), embracing low-carbon forms of transportation (e.g., active and mass transportation, electric vehicles), avoiding unnecessary air travel (e.g., vacationing closer to home), and embracing a healthy, sustainable diet (e.g., eating less red meat and more grains, fruits, and vegetables). They can multiply the impact of these actions by explaining to others—their family members, friends, neighbors, co-workers, members of their faith community—why they are taking these actions. Such modeling is effective; for example, people who know somebody who gave up flying because of climate change are more likely to change their own attitudes toward flying less (Westlake, 2017). Leading by example can enhance health professionals' motivations to take further actions (Gifford, Kormos, & McIntyre, 2011; Stankuniene, Streimikiene, & Kyriakopoulos, 2020) and makes their leadership more credible in the eyes of others (Attari, Krantz, & Weber, 2016).

Change can also begin at work. Many of the actions noted above are equally applicable to health professionals' work lives as they are to their personal lives. The trusted voices of health professionals, as noted above, can be compelling for patients. Seeing a bicycle in a physician's office sends an important message to patients. Clinicians can and should advise patients to reduce dietary meat and walk more, simply for the sake of the patients' health; if appropriate, they can explain that such behavioral choices also benefit the larger community and the planet.

Health professionals can achieve an even greater impact by influencing the policies of the health systems in which they work. Providing health care is energy-intensive. Power is currently produced predominantly with fossil fuels. Health professionals, individually and collectively, can implement policy changes in their clinic, hospital, hospital system, or national health service aimed at increasing energy efficiency, decarbonizing energy sources through purchasing and/or on-site production of clean energy, eliminating the use of super heat-trapping pollutants that are needlessly used in inhalants and anesthetics, and sourcing low-carbon-footprint supplies and equipment. As the health sector has considerable market power, such practices can help propel market transformation across many industries. And because hospitals and clinics are anchor institutions and leading employers in their communities, such practices can set an example for other businesses, amplifying their impact.

Health professionals who are teachers also have opportunities to teach their students about the relevance of climate change to human health, and the opportunities to advance health through climate solutions, thereby helping to ensure readiness and leadership among the next generation of health professionals. Health professionals who conduct research can contribute in two additional ways: by asking and answering important questions at the nexus of climate and health, and by modifying their research methods to reduce needless waste of energy and materials.

Arguably, health professionals—individually and collectively—can achieve their greatest impact by advocating with the public and policymakers for policies that will help stabilize the climate and improve health. Equitable climate and health policies can and should be implemented at all levels of government (cities and counties, states and provinces, as well as nations). Health professionals have a unique and necessary role to play in explaining the need for such policies and in advocating for their adoption. Beyond public policies, health professionals can also use their influence, their trusted place in society, to encourage, if not demand, that their nation's and the world's largest corporations also adopt policies that will help stabilize the climate and promote human health and wellbeing.

Health professionals can also promote decarbonization in the private sector, using their voices as university faculty members, pension fund stakeholders, and shareholders in public companies, to call for disinvestment from fossil fuel companies (Bergman, 2018; Law, Duff, Saunders, Middleton, & McCoy, 2018). Although controversial, divestment is widely recognized as an important tool in propelling the transition to a post-carbon economy (Hunt and Weber, 2018; McKibben, 2018).

Nor do health professionals have to limit themselves to informing and persuading decision-makers regarding the climate emergency; they can themselves aspire to political office. Perhaps the best-known example of a health professional leading on climate change is a physician and former Norwegian Prime Minister Gro Harlem Brundtland, but other physician and nurse elected officials from the global (e.g., Bhutan's Prime Minister Lotay Tshering) to the national (e.g., U.S. Representatives Jim McDermott, Lois Capps, Lauren Underwood, Raul Ruiz, Ami Bera, and Kim Schrier), to the state and local (e.g., California Assembly member Joaquin Arambula), have taken strong positions on climate change. Bringing the trusted voices of health professionals into executive and legislative branches of government is a powerful way to advance climate action.

Health professionals daily encounter the ravages of racism and poverty; they know that these injustices are leading causes of preventable suffering and premature death. They are well-positioned to bring that awareness to climate solutions—protecting vulnerable communities in adapting to climate-related hazards, and assuring that the benefits of decarbonization strategies are distributed equitably (Ebi & Hess, 2020; Rouf & Wainwright, 2020; Shue, 2014).

## More Powerful Together

As individuals, health professionals can achieve only so much. By working together, health professionals can maximize their impact.

Joining an organization that focuses specifically on climate and health is perhaps the easiest way for health professionals to align themselves with others seeking to advance climate and health solutions. Examples of such organizations include Alliance of Nurses for a Healthy Environment; Global Climate and Health Alliance; Medical Society Consortium for Climate and Health; and Physicians for Social Responsibility.

Another natural opportunity for physicians and other health professionals to work together is to influence the professional societies to which they already belong. Health professional societies should develop strong climate and health resolutions and policies and should advocate actively for equitable, health-promoting climate policies in state and federal governments. They are more likely to do so when their members initiate these actions.

Lastly, where there is a need, health professionals—and health organizations—can work together to create new organizations. For example, in 2016, several medical societies recognized the value of working together to unify and amplify the voice of medicine as a strategy to influence U.S. federal policy on the issue of climate and health. Together they launched the Medical Society Consortium on Climate and Health, which currently has 32 national medical societies as members, and more than 50 additional health organizations as affiliates and partners. With a coalition of aligned health organizations, the Consortium helped develop a Policy Action Agenda on Climate, Health, and Equity which guides the Consortium's advocacy activities, and has subsequently been endorsed by nearly 200 health organizations. After the 2020 U.S. election, with a coalition of health organizations that developed the Policy Action Agenda, the Consortium developed a comprehensive, "all-of-government," set of climate, health, and equity recommendations for the incoming Biden Administration and the new Congress to use in "protect [ing] our nation's health in the face of the climate health emergency."

As an outgrowth of the Medical Society Consortium on Climate and Health, in 2017 several physicians in Virginia organized the Virginia Clinicians for Climate Action to advocate for equitable climate and health policies in their state. Their collective actions have already had a significant demonstrable impact on enacting important climate and health legislation (see Box 1). Their success has inspired

**BOX 1 Health Professionals Advancing Climate and Health Policy in Virginia**

The voice of the health community was historically absent from the climate policy discussion in Virginia. Virginia Clinicians for Climate Action (VCCA) was formed in 2017 to fill this void. Since its inception, VCCA has helped build a network of health partners and over 450 clinician advocates for climate solutions. VCCA doctors, nurses, and allied health professionals write opinion pieces, attend hearings, issue statements, and positions, collaborate with medical societies on climate and health programs, meet with legislators, hold monthly educational webinars, and partner with hospital systems to hold climate and health conferences and lectures. VCCA's experience in Virginia demonstrates the power of unified a health voice to overcome barriers blocking the necessary transition to a clean energy economy. Health professionals and health organizations are becoming a powerful voice in climate and energy policymaking in the state. Having heard from VCCA members across Virginia, State Health Commissioner Dr. Norman Oliver established a Climate Change Committee at the Virginia Department of Health in 2019. In 2020, a circuit court overturned and vacated the permit for a proposed Atlantic Coast Pipeline compressor station, citing the health-based impacts on the local, majority African-American community. The pipeline was ultimately canceled, successfully concluding years of campaigning by impacted communities and environmental justice advocates. Subsequently, VCCA was joined by Healthcare Without Harm, Kaiser Permanente, Bon Secours Mercy Health, and the Virginia Chapter of the American Academy of Pediatrics, in support of landmark climate legislation, the Virginia Clean Economy Act (VCEA). This bill passed in 2020, making Virginia the first southern state to commit to 100 percent clean electricity by 2050. Furthermore, Virginia joined the Regional Greenhouse Gas Initiative (RGGI) in 2021. These policies will be enacted with a focus on equity—50 percent of the revenue generated by participating in RGGI will be allocated toward energy efficiency programs for low-income communities. RGGI was the first climate legislation ever supported by a Virginia medical society, the Virginia Chapter of the American Academy of Pediatrics, in 2015.

In 2021, VCCA joined partners to address transportation, the leading source of carbon pollution in the state. VCCA developed a report, webpage, and videos on the health effects of vehicle pollution in Virginia, and the health benefits of stronger vehicle emission standards. This report was recently cited in a press release from nine Virginia cities and counties supporting clean transportation. A unified health voice is proving its value in advancing climate policy in Virginia.

health professionals in over a dozen additional U.S. states to create state-focused climate and health.

The goal of the Paris Climate Agreement is arguably the world's most important public health goal. Successfully addressing the climate crisis requires high-level policy action—ambitious Nationally Determined Contributions through the U.N. Framework Convention on Climate Change, reversal of perverse economic subsidies at the international and national level, transformative changes in agriculture, transportation, urban planning, energy, and manufacturing policies. It also requires far-reaching behavioral changes—in the choices people make regarding how they eat, how they travel, how they consume goods, and how they use energy. And it requires bold private-sector action across the economy, from manufacturing firms to healthcare organizations. For each of these, the voices of health professionals can play a highly influential role.

## Notes

All authors contributed to the conceptualization and writing of this commentary.

Conflicts of interest: None declared.

**Corresponding author**: Edward Maibach, emaibach@gmu.edu

**Edward Maibach, MPH, PhD**, is a distinguished university professor of George Mason University, Fairfax, VA.

**Howard Frumkin, MD, DrPH**, is a professor emeritus at the University of Washington School of Public Health, Seattle, WA.

**Samantha Ahdoot, MD**, is an assistant professor of Pediatrics at the Virginia Commonwealth University School of Medicine, Arlington, VA.

## References

David, Abel, and Katya Spear. 2019. *Wisconsin Opportunity in Domestic Energy Production: The Economic and Health Benefits of 100% In-State Energy Production* [Online]. Madison, WI: University of Wisconsin COWS. https://cows.org/publications/Wisconsin-Opportunity-in-Domestic-Energy-Production-the-Economic-and-Health-Benefits-of-100-in-State-Energy-productio/ [accessed 29 February 2021].

Attari, Shahzeen, David Krantz, and Elke Weber. 2016. "Statements About Climate Researchers' Carbon Footprints Affect Their Credibility and the Impact of Their Advice." *Climatic Change* 138: 325–38. https://doi.org/10.1007/s10584-016-1713-2

Bergman, Naom. 2018. "Impacts of the Fossil Fuel Divestment Movement: Effects on Finance, Policy and Public Discourse." *Sustainability* 10: 2529. https://doi.org/10.3390/su10072529

Clemence, Michael. 2020. *Ipsos MORI Veracity Index 2020* [Online]. London: Ipsos MORI. https://www.ipsos.com/ipsos-mori/en-uk/ipsos-mori-veracity-index-2020-trust-in-professions [accessed 29 February 2021].

Chen, Leo, Gaurav Vasudev, Amanda Szeto, and Winston Cheung. 2018. "Trust in Doctors and Non-Doctor Sources for Health and Medical Information." *Journal of Clinical Oncology* 36: 10086. https://doi.org/10.1200/JCO.2018.36.15_suppl.10086

Ebi, Kristie, John Balbus, George Luber, Aparna Bole, Allison Crimmins, Glass Gregory, Saha Shubhayu, Mark M. Shimamoto, Juli Trtanj, and Jalonne L. White-Newsome. 2018. "Human Health." In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*, eds., Reidmiller, D. R., C. W. Avery, D. R. Easterling, K. E. Kunkel, K. L. M. Lewis, T. K. Maycock, and B. C. Stewart. Washington, DC: U.S. Global Change Research Program, 539–71. https://doi.org/10.7930/NCA4.2018.CH14

Ebi, Kristie, and Jeremy Hess. 2020. "Health Risks Due to Climate Change: Inequity in Causes and Consequences." *Health Affairs* 39: 2056–62. https://doi.org/10.1377/hlthaff.2020.01125

Gao, Jinghong, Sari Kovats, Sotiris Vardoulakis, Paul Wilkinson, Alistair Woodward, Jing Li, Shaohua Gu et al. 2018. "Public Health Co-Benefits of Greenhouse Gas Emissions Reduction: A Systematic Review." *The Science of the Total Environment* 627: 388–402. https://doi.org/10.1016/j.scitotenv.2018.01.193

Georgeson, Lucien, and Mark Maslin. 2019. "Estimating the Scale of the US Green Economy Within the Global Context." *Palgrave Communications* 5: 121. https://doi.org/10.1057/s41599-019-0329-3

Gifford, Robert, Christine Kormos, and Amanda McIntyre. 2011. "Behavioral Dimensions of Climate Change: Drivers, Responses, Barriers, and Interventions." *Wiley Interdisciplinary Reviews: Climate Change* 2: 801–27. https://doi.org/10.1002/wcc.143

Harmer, Andrew, Ben Eder, Sophie Gepp, Anja Leetz, and Remco van de Pas. 2020. "WHO Should Declare Climate Change a Public Health Emergency." *British Medical Journal* 368: m797.

Hathaway, Julia, and Edward Maibach. 2018. "Health Implications of Climate Change: A Review of the Literature About the Perception of the Public and Health Professionals." *Current Environmental Health Reports* 5: 197–204. https://doi.org/10.1007/s40572-018-0190-3

Hubbert, Ben, Moe Ahmed, John Kotcher, Edward Maibach, and Mona Sarfaty. 2020. "Recruiting Health Professionals as Sustainability Advocates." *The Lancet Planetary Health* 4: e445–46. https://doi.org/10.1016/S2542-5196(20)30225-4

Hunt, Chelsea, and Olaf Weber. 2018. "Fossil Fuel Divestment Strategies: Financial and Carbon-Related Consequences." *Organization & Environment* 32: 41–61. https://doi.org/10.1177/1086026618773985

Ipsos. 2019. *Global Trust in Professions: Who Do Global Citizens Trust?* [Online]. http://www.ipsos.com/sites/default/files/ct/news/documents/2019-09/global-trust-in-professions-trust-worthiness-index-2019.pdf [accessed 29 February 2021].

Valerie, Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia et al. 2018. "Global Warming of 1.5°c." An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty, eds. Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla PR, et al. Geneva: IPCC and WMO.

Kotcher, John, Edward Maibach, Jeni Miller, Eryn Campbell, Lujain Aldqodmani, Marina Maiero, and Arthur Wyns 2021. "Doctor's and Nurse's View on Climate Change and Health: A Multi-National Survey Study." Under review.

Law, Adam, Diedre Duff, Patrick Saunders, John Middleton, and David McCoy. 2018. "Medical Organisations Must Divest From Fossil Fuels." *BMJ* 363: k5163. https://doi.org/10.1136/bmj.k5163

Maibach, Edward, Mona Sarfaty, Mark Mitchell, and Rob Gould. 2019. "Limiting Global Warming to 1.5 to 2.0°C—A Unique and Necessary Role for Health Professionals." *PLOS Med* 16 (5): e1002804. https://doi.org/10.1371/journal.pmed.1002804

McKibben, Bill. 2018. "At Last, Divestment is Hitting the Fossil Fuel Industry Where it Hurts." *The Guardian* (December 16). https://www.theguardian.com/commentisfree/2018/dec/16/divestment-fossil-fuel-industry-trillions-dollars-investments-carbon [accessed 29 February 2021].

McMichael, Anthony. 2017. *Climate Change and the Health of Nations: Famines, Fevers, and the Fate of Populations*, Oxford, England: Oxford University Press.

Milner, James, Ian Hamilton, James Woodcock, Martin Williams, Mike Davies, Paul Wilkinson, and Andy Haines. 2020. "Health Benefits of Policies to Reduce Carbon Emissions." *BMJ* 368: l6758. https://doi.org/10.1136/bmj.l6758

Reinhart, R. J. 2020. *Nurses Continue to Rate Highest in Honesty, Ethics*. (Gallup Poll Social Series). https://news.gallup.com/poll/274673/nurses-continue-rate-highest-honesty-ethics.aspx [accessed 29 February 2021].

Rouf, Khadj, and Tony Wainwright. 2020. "Linking Health Justice, Social Justice, and Climate Justice." *The Lancet Planetary Health* 4: e131–32. https://doi.org/10.1016/S2542-5196(20)30083-8

Sarfaty, Mona, Mark Mitchell, Brittany Bloodhart, and Edward Maibach. 2014. "A Survey of African American Physicians on the Health Effects of Climate Change." *International Journal of Environmental Research and Public Health* 11: 12473–85.

Sarfaty, Mona, Brittany Bloodhart, Gary Ewart, George Thurston, John Balmes, and Tee Guidotti. 2015. "American Thoracic Society Member Survey on Climate Change and Health." *Annals of the American Thoracic Society* 12: 274–278. https://doi.org/10.1513/AnnalsATS.201410-460BC

Sarfaty, Mona, Jennifer Kreslake, Thomas Casale, and Edward Maibach. 2016. "Views of AAAAI Members on Climate Change and Health." *Journal of Allergy and Clinical Immunology in Practice* 4: 333–35.e326. https://doi.org/10.1016/j.jaip.2015.09.018

Shindell, Drew, Greg Faluvegi, Karl Seltzer, and Cary Shindell. 2018. "Quantified, Localized Health Benefits of Accelerated Carbon Dioxide Emissions Reductions." *Nature Climate Change* 8: 291–95. https://doi.org/10.1038/s41558-018-0108-y

Shue, Henry. 2014. *Climate Justice: Vulnerability and Protection*, Oxford: Oxford University Press.

Stankuniene, Gintare, Dalla Streimikiene, and Grigorios Kyriakopoulos. 2020. "Systematic Literature Review on Behavioral Barriers of Climate Change Mitigation in Households." *Sustainability* 12: 7369. https://doi.org/10.3390/su12187369

Watts, Nick, W. Neil Adger, Paolo Agnolucci, Jason Blackstock, Peter Byass, Wenjia Cai, Sarah Chaytor et al. 2015. "Health and Climate Change: Policy Responses to Protect Public Health." *The Lancet* 386 (10006): 1861–914.

Watts, Nick, Markus Amann, Nigel Arnell, Sonya Ayeb-Karlsson, Jessica Beagley, Kristine Belesova, Max Boykoff et al. 2020. "The 2020 Report of the Lancet Countdown on Health and Climate Change: Responding to Converging Crises." *The Lancet* 397: 129–70. https://doi.org/10.1016/S0140-6736(20)32290-X

Westlake, S. 2017. A counter-narrative to carbon supremacy: Do leaders who give up flying because of climate change influence the attitudes and behaviour of others? Available at SSRN: https://ssrn.Com/abstract=3283157

Whitmee, Sarah, Andy Haines, Chris Beyrer, Fredrick Boltz, Antony Capon, Braulio de Souza Dias, Alex Ezeh et al. 2015. "Safeguarding Human Health in the Anthropocene Epoch: Report of the Rockefeller Foundation—Lancet Commission on Planetary Health." *The Lancet* 386: 1973–2028.

World Meteorologic Organization. *The Global Climate in 2015-2019* [Online]. Geneva: WMO, 2019. https://library.wmo.int/index.php?lvl=notice_display%26id=21522#.YCCTOmiQGUk [accessed 29 February 2021].

World Medical and Health Policy



# Advancing Energy Justice as a Climate and Public Health Solution

**Rachel McMonagle, Ivana Castellanos, and Surili Sutaria Patel**

*Energy justice is a climate and health issue. Energy systems contribute to greenhouse gas emissions and negative health outcomes from energy extraction to consumption. Just as climate change disproportionately affects certain populations, energy also is a health equity issue. The U.S. energy sector faces a critical challenge of energy access and affordability that limits communities' ability to achieve good health. As alternative energies become cost-competitive, there is a need to monitor, evaluate, and support a transition to a healthier energy system. By pursuing energy justice as a priority, public health professionals can play a role in challenging health inequities, as well as mitigating the adverse health effects of climate change. Through a roundtable convening, public health leaders developed pathways for public health professionals to promote a just energy future. Considering public health upfront in energy system decision making may result in multidisciplinary thinking and solutions to improve health outcomes.*

**KEY WORDS:** energy, climate change, public health, health equity, justice, just transition

## Energy Justice: Introduction and Background

The U.S. energy sector is in a massive state of transition. For decades, the U.S. coal industry has been declining due to lower-cost natural gas and renewable energy options and policies designed to control greenhouse gas emissions (Mendelevitch, Hauenstein, & Holz, 2019). As alternative energies become cost-competitive and the Green New Deal triggers policy discussions, there is a need to monitor, evaluate and support a just transition to achieve net-zero greenhouse gas emissions for all communities and workers.

A just transition shifts the energy industry from consuming fossil fuels to using alternative energy sources, in a way that ensures workers' rights and offers economic opportunities and environmental health benefits for affected communities (Climate Justice Alliance, n.d.). This cultural, as well as economic, shift emphasizes





doi: 10.1002/wmh3.420

environmental sustainability in the face of climate change (Fairchild & Weinrub, 2017).

In the same way that climate change disproportionately affects certain populations, energy is a health equity issue. Energy insecurity, or the inability to adequately meet basic household energy needs, affects many U.S. households. Communities that lack energy services also often have poorer health outcomes, fewer educational and economic opportunities, limited political representation, and inadequate access to health care (Sovacool & Jones, 2013). Children in energy-insecure homes are at greater risk for poor health, hospitalizations, and developmental delays (Cook et al., 2008). Throughout the U.S., energy insecurity is linked to housing instability, food insecurity, and health challenges (Hernández, 2013).

Households that identified as racial or ethnic minorities or low-income experience more energy insecurity (U.S. Energy Information Administration, 2015) Additionally, households earning more than $50,000 spend only 3 percent of their income on energy compared with households making less than $10,000, which spend 33 percent of their income on energy (Trisko, 2014). Low-income households often face an energy burden that is three times higher than other households (U.S. Department of Energy, 2018). The most recent data published by the United States Energy Information Administration in 2015, states:

- 31 percent of U.S. households reported struggling to pay energy bills or to maintain adequate heating and cooling in their homes.
- 11 percent of households reported keeping their home at unhealthy or unsafe temperatures due to costs.
- About one in five households reported reducing or forgoing basic necessities like food and medicine to pay an energy bill.
- 14 percent of households reported receiving a disconnection notice for energy service.

Advancing energy justice challenges these inequitable structures within the U.S. energy system. Energy justice is the principle that all people should have (i) a reliable, safe, and affordable source of energy; (ii) protection from a disproportionate share of costs or negative impacts or externalities associated with building, operating, and maintaining electric power generation, transmission, and distribution systems; and (iii) equitable distribution of and access to benefits from such systems (Joroff, 2017).

Energy justice advances a global energy system that fairly disseminates the costs and benefits of energy services and contributes to more representative and impartial energy decision making (Sovacool, Heffron, McCauley, & Goldthau, 2016). Given that the core outcomes of energy justice are aligned with the values of public health practitioners, energy justice can be viewed as a public health solution to climate and health inequities.

## The Role of Public Health Professionals in an Energy Just Future

The American Public Health Association's Center for Climate, Health, and Equity is working to elevate public health and health equity in the discourse on a just energy transition. By pursuing energy justice as a priority, public health professionals can play a role in challenging health inequities, as well as mitigating the adverse health effects of climate change. Including public health as a consideration, in the beginning, can result in multidisciplinary thinking and solutions to improve health outcomes.

On November 3, 2019, American Public Health Association (APHA) hosted its third Climate Changes Health Roundtable, an interactive meeting at the 2019 APHA Annual Meeting in Philadelphia, PA. The purpose of the meeting was to bring together climate and health practitioners to discuss energy justice and health. It provided a rich opportunity for APHA to deepen its role in the climate mitigation sphere and explore topics largely undiscussed in traditional climate and health discussions.

Over 70 climate and health champions from more than 50 organizations and institutions discussed key questions concerning energy justice in the United States for 2 hours. Findings from three of the critical questions are explored here.

### *How Do U.S. Energy Transitions Build From and Contribute to Environmental Injustices and Public Health Issues?*

For over 60 years, the environmental justice movement has raised awareness that people of color and low-income communities often bear the brunt of "brown" environmental issues, while white and more affluent communities enjoy the benefits of "green" environmental benefits. In the context of energy, race—even more than class—is the number one indicator for the placement of toxic facilities in this country (NAACP, n.d.).

Difficulty in accessing the political, economic, social, and environmental resources that enable people to cope with climate threats, such as extreme heat and natural disasters, can contribute to a potentially unmanageable energy burden as climate change worsens. Climate change exacerbates health inequities, disproportionately harming the most vulnerable among us—children and pregnant women, people with low income, the aged and people with disabilities and chronic illnesses, some communities of color, indigenous peoples and tribal communities, immigrants and outdoor workers, to name a few.

With each type of energy supply, there are unique impacts on human health and the environment. The detrimental environmental and health consequences of fossil fuel extraction and consumption are well-documented (American Public Health Association [APHA], 2018). Air pollution caused by fossil fuel combustion at coal and natural gas plants and transportation-related pollution create health concerns where energy is produced. In the communities where extraction takes place (e.g., coal mines, natural gas drilling), air and water pollution impact health, and workers suffer from occupational diseases such as pneumoconiosis, or black lung disease.

Renewable energy sources, such as solar, wind, tidal, and hydropower, can also have negative externalities (APHA, 2018). Renewable energy development, although safer from a climate perspective, poses occupational and environmental health concerns where equipment is manufactured and installed (APHA, 2018).

Energy efficiency measures are a common strategy employed to decrease energy demand and, subsequently, decrease energy and health costs on households (Shove, 2018). Unfortunately, efficiency modifications are often expensive to install or build given initial investment costs. Low-income communities experience the greatest energy costs due to older housing infrastructure and long-term disinvestments (Evans, 2004).

For low-income households that rent, a lack of maintenance by landlords or landlords' selection of lower quality fixtures in housing structures can further increase energy costs (Evans, 2004). Energy-insecure households also disproportionately encounter inefficiencies in the home, like older and less efficient appliances and drafts that induce heat loss (Hernández, 2013).

Given the complexity of interacting factors, it is essential to consider historical and structural inequities that contribute to the current unjust state of the U.S. energy system. As an energy transition advances, actors must ensure that new policies and programs do not exacerbate or contribute to existing inequities.

### *What Does an Energy Just Future Look Like for the United States?*

Critical components of an energy just future in the United States:

- The energy sector is founded in a just economy, shifting to a paradigm valuing human well-being. The risks and benefits of energy production and consumption are more equitably distributed across place, people, and time. Affordable energy is available continuously and resilient to climate threats.
- The energy sector shifts to not-for-profit public ownership. Power is distributed and owned by the community. Profits are reinvested locally with sustainability and equity in mind. Communities with fewer resources and opportunities are prioritized, and information regarding opportunities is available and accessible to all.
- Fossil fuels are phased out and safe, renewable energy is promoted. Existing infrastructure is used for new centralized renewable power, eliminating the dirtiest energy first to achieve health co-benefits as soon as possible.
- Relevant sectors (e.g., building, agriculture, health care, to name a few) are engaged with a just transition.

*What Role Can Public Health Professionals Play in the Policy or Program Development of a Just Transition?*

Priority actions through which the public health field can promote a just energy future:

1. Invest in affected communities to align energy policy and decision making power with community leadership and solutions.

- Align policy and leadership with community solutions to energy.
- Bring community members to the decision making table.
- Identify and advocate with and for populations that are burdened or threatened by energy injustice with particular attention to frontline communities.
- Prioritize affordable renewable energy in low-wealth communities.
- Examine the justice implications of transitioning to a safe, renewable energy economy.
- Center localized power with microgrids of renewable energy as an alternative to centralized public utility companies.
- Advocate with and for underrepresented frontline tribes and communities that are protecting "unused" land, which various energy interests see as available.
- Prioritize energy efficiency and affordable alternative forms of energy in low-wealth communities and communities of color.
- Invest in affordable housing and design land-use policies to avoid displacement and reduce long-distance commuting.

2. Develop educational resources and action-based interdisciplinary partnerships for energy justice.

- Develop educational resources and templates for testimony or amicus briefs.
- Use national conferences as platforms to inspire action on energy justice.
- Train fossil fuel workers with new employable skills.
- Engage the healthcare sector and providers, the transportation sector, the building and housing sectors, faith-based communities, utility companies, state energy regulators, public utility commissions, consumers and consumer advocate groups, and nonprofits working on energy efficiency and environmental justice.
- Work with powerful messengers, public health nurses, and in-home healthcare service providers and voices from the private sector.
- Reimagine transportation.
  - Develop affordable public transportation systems and multi-modal streets that allow space for safe biking, walking, rolling, etc. with increased access in low-wealth communities and communities of color.

  - ○ Tax new non-green cars or gas.
  - ○ Incentivize public transportation and electric car use.
  - ○ Funnel toll funding to new channels, such as green transportation or equity initiatives.

3. Quantify the health impacts and costs of energy injustice to support policy and culture change that prioritizes a just economy and human well-being.

- Finance research on new energy sources and clean-up strategies for existing environmental health conditions.
- Benchmark and monitor energy efficiency performance.
- Retrofit home energy systems to benefit tenants, that is, weatherization or alternative energy.
- Promote energy efficiency in the home and public operations.
- Monitor community displacement and climate gentrification.
- Lobby for fuel-efficiency standards and promote independence from fossil fuel resources.
- Include equity in energy policies.
- Support policies that support a just transition for workers and communities adversely impacted by climate change and the transition to a low-carbon economy.
- Restructure public expenditures to improve transportation systems and infrastructure.
- Encourage transportation agencies to prioritize transportation carbon reductions in their missions and budgets.

## Conclusion and Next Steps

A just transition is often inappropriately imagined solely as an economist's or environmentalist's task to bear when energy justice is really a public health and health equity issue. A wide array of actors is critical for sustainable systemic transformation of the energy sector, and public health professionals can lead the way.

There are historical and structural inequities and ongoing injustices that will need to be fully addressed throughout a sustainable just transition. Public health professionals are uniquely qualified to guide this reinvestment of policy and resources to build an economy that values human well-being over profits.

While no single entity can take on the entirety of the proposed set of priorities to advance an energy just future, public health associations and individuals can each play a part in pursuing the critical components to advance energy justice.

**Rachel McMonagle, MEM**, is the climate change program manager at the American Public Health Association.

**Ivana Castellanos, MPH**, is a policy analyst at the American Public Health Association.

**Surili Sutaria Patel, MS**, is the director of the Center for Climate, Health and Equity at the American Public Health Association.

## Notes

This material is based on work supported, in part, by The Kresge Foundation, the Centers for Disease Control and Prevention, and the American Public Health Association. Special thanks to Adrienne Hollis, JD, Ph.D. for her facilitation of the 2019 Climate Changes Health Roundtable at the APHA Annual Meeting and Expo. The views expressed in this article are those of the authors and do not necessarily represent the position or policy of the organizations or individuals aforementioned.

Conflicts of interest: None declared.

**Corresponding author**: Rachel McMonagle, rachel.mcmonagle@apha.org

## References

American Public Health Association (APHA). 2018. *The Public Health Impact of Energy Policy in the United States* [Online]. November 13. https://apha.org/policies-and-advocacy/public-health-policy-statements/policy%20database/2019/01/28/public-health-impact-of-energy-policy

Climate Justice Alliance. n.d. *Just Transition: A Framework for Change* [Online]. https://climatejusticealliance.org/just-transition

Cook, J. T., P. H. Casey, R. Rose-Jacobs, M. M. Black, M. Chilton, S. E. deCuba, D. Appugliese et al. 2008. "A Brief Indicator of Household Energy Security: Associations With Food Security, Child Health, and Child Development in U.S. Infants and Toddlers." *Pediatrics* 122 (4): e867–75.

Evans, Gary. 2004. "The Environment of Childhood Poverty." *American Psychologist* 59 (2): 77–92.

Fairchild, Denise, and Al Weinrub. 2017. *Energy Democracy Advancing Equity in Clean Energy Solutions*, Washington, DC: Island Press.

Hernández, D. 2013. "Energy Insecurity: A Framework for Understanding Energy, the Built Environment, and Health Among Vulnerable Populations in the Context of Climate Change." *American Journal of Public Health* 103 (4): e32–34.

Joroff, Aladdine. 2017. *Energy Justice: What it Means and How to Integrate it Into State Regulation of Electricity Markets* [Online]. Environmental Leadership Program, Environmental Law Institute, November 1. https://elpnet.org/energy-justice-what-it-means-and-how-integrate-it-state-regulation-electricity-markets

Mendelevitch, R., C. Hauenstein, and F. Holz. 2019. "The Death Spiral of Coal in the U.S.: Will Changes in U.S. Policy Turn the Tide?" *Climate Policy* 19 (10): 1310–1324. https://doi.org/10.1080/14693062.2019.1641462

NAACP. n.d. *Environmental & Climate Justice* [Online]. www.naacp.org/issues/environmental-justice

Shove, E. 2018. "What is Wrong With Energy Efficiency?" *Building Research & Information* 46 (7): 779–89. https://doi.org/10.1080/09613218.2017.1361746

Sovacool, Benjamin K., Roman V. Sidortsov, and Jones, Benjamin R. 2013. *Energy Security, Equality and Justice*, London: Routledge.

Sovacool, Benjamin K., Raphael J. Heffron, Darren McCauley, and Andreas Goldthau. 2016. "Energy decisions reframed as justice and ethical concerns." *Nature Energy* 1 (5): 16024. http://doi.org/10.1038/nenergy.2016.24

Trisko, Eugene M. 2014. *Energy Cost Impacts on American Families, 2001–2014* [Online]. February http://www.americaspower.org/wp-content/uploads/2015/09/download-our-new-report.pdf

U.S. Department of Energy. 2018. *Low-Income Household Energy Burden Varies Among States—Efficiency Can Help in All of Them* [Online]. December. https://www.energy.gov/sites/prod/files/2019/01/f58/WIP-Energy-Burden_final.pdf

U.S. Energy Information Administration. 2015. *Residential Energy Consumption Survey 2015* [Online]. https://www.eia.gov/consumption/residential/reports/2015/energybills

World Medical and Health Policy



# Book Review

Ronald C. Kramer, *Carbon Criminals, Climate Crimes. New Brunswick: Rutgers University Press, 2020. Paperback. pp. 230. ISBN: 9781978805583.*

In this important book, Ronald Kramer calls on criminologists to contribute to a global, integrated, mass social movement demanding actions to halt climate change. The book provides a concise reference describing the reality of and harms from climate change; knowing environmental destruction by corporate and state actors over more than sixty years; failures of past attempts to reduce greenhouse gases through legislation, executive orders, regulations, litigation, and international agreements; and challenges currently facing climate activists. By applying criminology analysis and focusing on climate crimes, this book is distinct from the many climate change tomes by climate activists, earth scientists, public health experts, or environmental economists. Moreover, the author relates his inspiring personal journey, commitment, and hope—from professor of sociology specializing in corporate and state criminology to climate social activist.

Kramer relies on scholarship identifying the core characteristics of "crime" as morally blameworthy harms, public condemnation, and state sanctions. In weighing climate-affecting actions, he instructs readers that these elements of crime invite conceptualization far beyond the confines of what is usually thought of as criminal law and criminal justice, sweeping in diverse forms of expressing moral outrage and imposing burdens. The author labels a wide range of actions as climate crimes, including extracting, marketing, and burning fossil fuels, erasing scientific data from federal government websites, U.S. military interventions in the Mideast, militarized responses to drought-induced migration, and failure to reach a binding international agreement to hold global warming to 1.5°C.

Ultimately, Kramer blames climate change on "state-corporate crimes within a global capitalist political economy" (p. 7) and treadmills of production and destruction (p. 178). He adds a potential international crime of ecocide (p. 209). Despite identifying many climate crimes, Kramer finds the criminal justice system inadequate to meet the pressing challenges of climate change. He concludes that halting climate crimes and achieving climate justice require a global nonviolent



doi: 10.1002/wmh3.393

insurgency together with restructuring the capitalist economic system, not relying on more criminal laws and prosecutions.

Criminologists and all other professionals should work toward climate solutions. Regrettably, Kramer does little to call on attorneys, particularly criminal prosecutors and defense lawyers, to develop the knowledge and skills to litigate climate-related cases. Unless attorneys join in the fight against climate crimes, Kramer's hopes for publicly shaming blameworthy corporate and state actors and spurring a global insurgency movement will be handicapped.

Kramer does explore a few areas of criminal law. Most prominently, he describes the securities fraud claims brought by the New York Attorney General against ExxonMobil, which were dismissed after a trial in December 2019. Kramer also notes that climate change is fueling violent crimes in the Global South and criminal prosecution of immigrants, and mentions the necessity defense asserted by climate activists facing criminal trespass charges from interfering with an oil pipeline. Nevertheless, criminal lawyers will find little inspiring (or perhaps even little credible) in Kramer's broad approach to the elements of climate crimes based on principles of human rights and morality or the common law public trust doctrine protecting natural resources.

Lawyers should be trained and motivated to contribute to remedying climate crimes. The opportunities are richer than Kramer portrays, as illustrated by six criminal settlements with energy companies. In 2020, in connection with California wildfires (fueled by extreme heat and drought), the Butte County District Attorney and Pacific Gas & Electric Co. entered an agreement under which the company pled guilty to involuntary manslaughter and starting a fire, and paid $3.5 million in statutory penalties. Next, a 2016 claim brought by the Los Angeles County District Attorney against Southern California Gas Co. ended with the company pleading no contest to a misdemeanor for failing to timely report leaking natural gas (a potent greenhouse gas), and paying millions of dollars in fines, penalties, and upgrades to facilities and systems. Also, the New York Attorney General in 2008–15 settled financial fraud investigations under the Martin Act's criminal and civil provisions with four energy companies (Xcel, Dynegy, AES, and Peabody Coal), requiring disclosures of climate risks in securities filings. Moreover, in 2019, Senators Bernie Sanders and Elizabeth Warren called for holding corporate executives, including in fossil fuel companies, criminally liable for knowingly destroying the planet.

Additionally, Kramer's global insurgency and civil disobedience against climate crimes will require the services of criminal defense attorneys. Protesters against oil and natural gas pipelines and coal shipments have been charged with criminal trespass, burglary, criminal mischief, disturbing the peace, and violations of the federal Racketeer Influenced and Corrupt Organizations Act and a state Riot Boosting Act. Their lawyers have had mixed results in asserting climate necessity defenses.

Regarding more common crimes that are multiplied by climate change (such as increases in domestic violence, street violence, and looting during heatwaves and floods), law enforcement authorities and communities should build resilience and lawyers should be prepared for such representations. Overall, criminal attorneys must be part of the response called for by the American Bar Association's 2019 resolution for “lawyers to engage in pro bono activities to aid efforts to reduce greenhouse gas emissions and adapt to climate change.”

Kramer's book should motivate widespread actions against climate crimes, both through social movement and the criminal justice system. Multiple strategies are needed to win the war for our families' health and welfare.

Warren Lavey Adjunct Professor
*Senior Fellow, Environmental Law and Policy Center,*
*University of Illinois,*
*Chicago, USA*
*Email: lavey@illinois.edu*

World Medical and Health Policy



# Book Review

Joan Fitzgerald. *Greenovation: Urban Leadership on Climate Change. New York: Oxford University Press, 2020. Hardback. pp. 246. ISBN 978-0-19-069551-4.*

The transition toward more sustainable cities that address climate change is a global challenge. The ability of urban leadership to guide this transition is critical as urban centers are the main contributors to climate change pollution. This book by Joan Fitzgerald presents Greenovation by giving an overview of policies in North America and Europe. Strategies, successes, opportunities, and obstacles toward more sustainable cities are highlighted. The simple format makes the book easy to navigate and includes acknowledgments, a short table of contents, notes, a bibliography, and an index. The writing is easy to understand making it accessible outside of the academic community.

The author is an expert on urban and public policy and urban climate action. In this work, she presents an urgency for cities to reduce their carbon footprints and provides examples showing *how* elected officials, planners, and other stakeholders, design, implement and create effective policies and programs to reduce greenhouse gas emissions. According to Fitzgerald, "To a surprising degree, cities have been innovators, instigators, and channels for public engagement in addressing the climate crisis" (p. 206). This is an interesting read for anyone trying to understand or implement policies to address climate change or sustainability within cities especially in North America or Europe. The primary argument of the book is that "cites are limited by state and national policy mandates and restrictions for good or for bad, as well as by their own fiscal limits. Yet, cities are on the front lines of both the impact of climate change and the effort to devise creative responses" (p. 205).

The book illustrates in detail the challenges faced among cities, states, and countries in meeting sustainability goals. At first glance, the book title "Greenovation" could be interpreted as an all-encompassing word for sustainability-related topics, such as climate change adaptation, environmental protection of air and water and especially the growing topic of greening cities. However, the author focuses on three areas: energy efficiency, renewable energy, and transportation efficiency.



doi: 10.1002/wmh3.419

Fitzgerald highlights the importance of political circumstances surrounding the successful implementation of sustainability measures, such as bipartisan support. The U.S. polarized two-party system and related politics may serve as a major barrier toward meeting sustainability goals. This is certainly different from Germany, often mentioned in the book, which possesses a multiparty system. Sporadically throughout the book, the idea of "carrots and sticks" referring to mechanisms of incentivizing or disincentivizing sustainability are presented. Examples include cost-saving mechanisms, mandates, and bureaucratic streamlining. More emphasis on these types of findings would have made the book more practice-oriented and hands-on.

Through real-world examples, the book highlights the influence of constitutional and state regulations and legal restrictions on the ability of local governments to act on climate change. One such example is the difference between home rule states or those states that have been given permission to self-govern, versus nonhome rule states. The author makes it clear that certain approaches that may be effective in encouraging cities toward addressing climate change in Europe may not be applicable to American cities. For instance, the implementation of efficient heating systems in some European cities has been based on requirements for building owners to connect to the centralized heating district. This is not legally enforceable in most American cities.

As indicated by the author "This book only begins to document the success and the promise of cities in the struggle to maintain and improve a habitable earth" (p. 206). Indeed, more examples of successful Greenovation not just in Europe and the United States, but also in Asia, Africa, and Latin America are needed to guide cities and urban leadership globally in their transformation to lead on climate change.

Jessica Hemingway
*The Leibniz Institute of Ecological Urban and Regional Development*
*Dresden, Germany*

World Medical and Health Policy



# Book Review

Julie Sze. *Environmental Justice in a Moment of Danger. Oakland, CA: University of California Press, 2020. pp. 144. ISBN 9780520300743.*

Julie Sze is a Professor and the Founding Chair of American Studies at UC Davis, as well as the Founding Director of the Environmental Justice Project at UC Davis. Her research focuses on urban environmental justice and climate change in the United States and China, and she has published two books and several peer-reviewed journal articles on this topic. This book contributes to both the field of environmental studies and to environmental justice by succinctly outlining the structural factors that contribute to environmental injustices. The writing is clear and concise, and is easily accessible for both lay and professional audiences, regardless of their previous exposure to this topic.

Although Sze's previous books focus on specific urban areas, her newest book offers a broader national perspective. This short, timely book traces how environmental injustices manifest across racial and economic lines, as well as the role of environmental justice movements in rectifying these multilevel injustices. Julie Sze helps us understand historical and cultural forces and resistance to violence, death, and destruction of lives and bodies through movements, cultures, and stories in highlighting who is involved and how. One of Sze's central arguments is that it is precisely in this moment that understanding environmental justice movements is essential. Environmental justice, a social movement to further policy and cultural changes that support intersectional social justice and environmentalism, was, and remains, about expansion, connection, and change, governed by a belief in mutuality. Sze discusses how environmental violence, or the environmentally unsustainable extraction of natural resources, is built into the history of the United States, part and parcel of a political-economic system based on racialized extraction of land and labor, such as in the case of Indigenous peoples. She also shows how capitalism depends on control, specifically control of nature, by relying on the control and abuse of people of color. People of color, especially African Americans and Indigenous peoples, have been historically made to live within environmental and bodily risk, specifically dispossession and racism. Sze uses disasters



doi: 10.1002/wmh3.390

and structural environmental violence as twin frames to prioritize the voices and histories of the environmental justice movement. She shows how environmental justices are interconnected with the worldview that its advocates advance. Specifically, she focuses on intersectionality organized around social and racial justice, whereas polluters and government agencies argue for separation. In doing so, Sze reminds her readers that climate justice is also a question of responsibility and morality and that environmental justice movements are freedom struggles through imagining and enacting solidarity, radical hope, anti-consumerism, and anti-capitalism. Ultimately, this book offers a primer for those who intuitively understand that environmental racism and environmental injustice exist in far too great measures and who want to make the world less structured by and invested in racism, class inequality, gender violence and attacks on refugees, immigrants, and Indigenous rights and land claims.

Throughout her book, Sze discusses several poignant and ongoing real-world examples of environmental injustice. Chapter 1 focuses on the Standing Rock Sioux's opposition to the Dakota Access Pipeline (DAPL) and how the battles therein are examples of environmental justice struggles writ large. Sze examines dispossession, production, extraction, and violence to conceptualize climate justice, war and militarism, and police violence. Standing Rock and the #NoDAPL movement represent the possibilities and perils of solidarity in a moment of great disruption in the lives and lands of Native peoples. Native perspectives are central to the environmental justice movement, evidenced in the 1991 "Principles of Environmental Justice." Sociologist David Pellow argues that these principles, which recognize the inherent worth of nonhumans, are radical in that they oppose racism, patriarchy, the excesses of the state and market forces, speciesism, imperialism, and ecological harm.

Chapter 2 draws the reader's attention to Flint, Michigan and Central Valley, California as the sites of environmental racism, a result of government policy based on active neglect and of concentration of corporate and business power at the expense of democracy or justice. This chapter examines how premature death, through lead poisoning in particular and toxicities in general, is woven into the economic and literal landscapes of the postindustrial city and the agricultural "factories in the field." In both Flint and Central Valley, water has transformed from a source of life to a product that, in its worst iteration, leads to premature death. In Flint, a majority African American city, residents, including vulnerable children, were exposed to high levels of lead and told everything was fine by agencies that were supposed to protect their environment and health. In Central Valley, a majority immigrant region, water and other pollution and contamination happen because water injustice is literally and ideologically built into the political-economic system, meaning that the unincorporated communities have no water system by design. In both towns, storytelling techniques are used to powerful effect against the techno-scientific façade of normalized and slow violence. Done with a political stance based on collective power and the democratizing impulses of art, performance, storytelling, and knowledge-making, these collaborations can be incredibly impactful. Flint and Detroit residents organized their own research projects in the face of government neglect and criminal behavior, such as Raise it Up!, a youth-centered intersectional arts organization. Sharing stories is a powerful attempt to correct the "flood" of neoliberalism in a world where global warming and water shortages loom large, and Sze shows how local storytelling organizations de-normalize existing environmental and social conditions of slow and fast violence.

Chapter 3 examines environmental and social disasters to show where and how radical hope is generated in dark times. Sze discusses Hurricanes Katrina and María as examples of the urgency of the political moment generates a radical momentum, created and reflected through culture. This chapter highlights how violence that is never reckoned with can never be forgotten, particularly in the wake of the racially disproportionate effects of climate change. Local residents, especially those who have been displaced, associate hurricanes like Katrina with social and economic disasters like top-down economic development and gentrification in black communities. This question of how to maintain hope and believe in renewal in the face of social and environmental violence, death, and destruction is being asked and answered on a daily basis in Puerto Rico. Puerto Rico still struggles in the aftermath of Hurricane María, which almost destroyed the island's infrastructure in September 2017. Sze calls the reader's attention to the stark debt crisis and austerity politics in Puerto Rico, which María only exacerbated. Using the frames of just transition and just power, a coalition of local, community-based organizations in Puerto Rico and on the mainland has called for such a just recovery, one that includes debt relief, transparency in distribution of resources, and attention to environmental justice issues, principles, and policies. In Puerto Rico, social movements are advancing radical and participatory democracy via the creation of art in the face of anti-democratic restructuring. Thus, culture becomes a resource in a context where climate injustice grows as a direct consequence of continuing coloniality, privatization, and racist policies.

Reorganizing environmental justice means taking the standpoint of African American and Indigenous lives as the starting point. Hurricanes Katrina and María show how existing political and environmental systems perpetuate deep social, spatial, and racial injustices. Environmental justice movements make links, within the United States and across borders, and create cultures of solidarity. The links between urban policing and pipeline violence, between oil production/extraction and gentrification, are themselves interconnected. Art-making and protest are life-affirming in an extractive capitalist context that invites death—of nature, peoples, and planet. Revolution means engaging with radical hope and a focus on praxis and social movements.

Although this book makes practical and sound recommendations for policy reform, it would benefit from providing first-hand interviews with displaced persons. Sze provides persuasive interview quotes from theorists and social movements leaders, but there is a dearth of feedback from on-the-ground people whose first-hand experiences would be valuable in developing policies that combat environmental injustices. In the future, conducting qualitative interviews would strengthen Sze's research by providing practical feedback from the people who are living and struggling with environmental injustices.

All in all, this book is a concise and powerful description of environmental injustices in various settings across the United States and its territories.

Shir Lerman Ginzburg
*Department of Public Health Sciences, UConn Health, University of Connecticut Health Center*
*Farmington, CT, USA*

World Medical and Health Policy



# Book Review

Méndez, Michael. *Climate Change from the Streets. Yale University Press, 2020. pp. 304. ISBN 9780300232158.*

Implementation of policies to address climate change has become a hot-button and polarizing topic with multiple angles, approaches, and perspectives. Pulling back the curtain a bit, Michael Méndez describes and analyzes, through a series of case studies, the various players and stakeholders as they each work legislative circles to ensure that their interests are defended and supported, often to the exclusion of other stakeholders. In addition, the text explores the often-overlooked challenges to public health that result from inequitable distribution of polluting industries and fallout.

Méndez, faculty at UC Irvine in the School of Social Ecology in the Department of Urban Planning and Public Policy, has been awarded several NIH grants exploring climate-related policies and published numerous articles in peer-reviewed journals on the topic, demonstrating unique expertise in the area. In *Climate Change from the Streets*, Méndez uses his time as a policy advisor, senior legislative consultant, and lobbyist during the legislative efforts to pass and implement climate change laws in California as a foundation for his research into the often-overlooked perspective of local environmental justice advocates and the role of large climate change initiatives in further marginalizing local communities in California and the Global South.

Throughout the book, Méndez combines story, research literature, and case study methods to develop a compelling narrative about the inclusion of the populations and communities most impacted by climate change. Furthermore, Méndez argues that in order to adopt socially conscious climate change policy, community voice and embodied expertise must be included and prioritized in policy planning and evaluation to develop stronger, more equitable climate change policy that does not further exacerbate existing health inequities in the United States and abroad.

---

[Article updated March 18, 2021 after first online publication: The second paragraph was corrected to list UC Irvine as Michael Méndez's institution.]



doi: 10.1002/wmh3.416

This book builds on the concepts of community-based participatory research and practice, specifically using the principles and concepts of Community Based Participatory Research (CBPR) to develop equitable policies in climate change legislation, adoption, and implementation. The argument supporting community inclusion is built by braiding existing literature, direct observations, and case studies that weave concepts of CBPR (e.g., Shared decision making and prioritized community expertise) to compare and contrast policy developed and implemented with and without impacted community participation.

For example, Chapter 4: *Changing the Climate from the Streets of Oakland*, discusses the formation and actions of the Oakland Climate Action Coalition (OCAC), which included a cross-section of social justice and grassroot organizations such as faith-based organizations, reproductive rights groups, labor unions, and green groups. The OCAC developed benchmarks and strategies to ensure that Oakland's climate change plan would meet the group's demands and benchmarks. The chapter outlines the strategies and steps that were taken to engage support from multiple local players and stakeholders.

There are few examples of community engagement applied to policy development or implementation. Dr. Méndez's *Climate Change from the Streets* advances the field of policy to include aspects of community-based participatory research and practice as applied to climate change legislation and implementation. The recommendation for these changes extend to other types of policy as well, including issues of gentrification and access to health care. Additionally, the arguments presented and supported throughout the text also point to significant ways in which climate change efforts should focus on the local changes involved in global climate change initiative and policies. The theses are informative and critical of neoliberal ideals that drive U.S. climate change policy and provide several examples for why and how the rights of local community need to be considered.

Readers with a background and understanding of concepts and issues around marginalization of impoverished communities of color and indigenous peoples globally, and the processes of community and institutional empowerment and community engagement will get more from the book than readers just coming to this idea. In other words, the intended audience seems to be individuals that are already concerned about the health and potential extra burdens that will be placed onto these communities as corporate entities fight localized climate policy in favor of cap and trade.

As an instructor in a large public university system, I am always looking for books for inclusion in classes on public health, health policy, and community engagement. Although the text as a whole is complex and assumes a general level of knowledge about health, social determinants of health, and concepts of community-based participatory research and practice, the book would provide a good place to generate rich in-class discussions around complex issues surrounding social determinants of health, marginalization (domestically and abroad), climate change and policy for advance undergraduate and graduate students.

This book is likely to be an excellent primer for discussion and provide a starting point for the exploration of policy informed by the community. The methods used in this book provide an excellent framework for policy work in not only climate change, but in many other areas of health inequities. In particular, the interactive use of narrative, case study, and epidemiology to explore and identify relevant strategies, while authentically incorporating community or embodied expertise provides a useful framework for other scholars that wish to research national and statewide policies impact within communities throughout the United States.

Jason Daniel-Ulloa
*University of Washington, Bothell, WA, USA*

World Medical and Health Policy

# Book Review

Tim Krieger, Diana Panke, and Michael Pregernig, eds. *Environmental Conflicts, Migration and Governance.* Bristol, UK: Bristol University Press, 2020. pp. 254. ISBN: 978-1529202168.

Are destructive environmental events, including those associated with climate change, going to send us barreling toward a future of mass human displacement?

For researchers and policymakers invested in asking questions like this, *Environmental Conflicts, Migration and Governance* provides an interdisciplinary exploration of the evidence that currently exists at the nexus of environmental and resource-related conflicts and migration, and the role of governance in this relationship. Released this year by Bristol University Press and edited by Tim Krieger, Diana Panke, and Michael Pregernig, the book is a timely investigation of this intersection at a moment when such debates as the classification of climate refugees or effective, rights-based governance in a changing global environment are centerstage.

The myriad disciplines represented by the 19 contributors make the collection extremely accessible for a diverse audience. In particular, this book serves as a strong orienting resource for those in fields such as environmental peacebuilding, disaster preparedness, and complex emergencies. *Environmental Conflicts, Migration and Governance* is edited broadly into four sections, covering:

1. How environmental and resource conflicts cause people to migrate.
2. Who migrates, when they migrate, how they migrate, where they end up, and how this relates to the environmental change in the origin country and the anticipated effects in the host country.
3. The political regulation of conflicts and migration through national, regional, and international regimes.
4. The impact of migration on host countries and countries of origin.

Krieger, Panke, and Pregernig have essentially developed a powerful starter kit for audiences looking for an entry point into understanding the scope of the existing literature (and knowledge gaps) in the relationship between environmental conflict, population movement, and governance. Behavioral scientists might find



doi: 10.1002/wmh3.394

particular interest in Diane C. Bate's chapter on individual and small group decisions regarding migration due to slow versus sudden-onset environmental events, or Marc Helbling's analysis of how an immigration policy's restrictiveness interacts with economic and political factors (such as colonial linkage) to impact its efficacy. For issue experts, J. Andrew Grant's comparison of regimes created to prevent the trade of conflict-prone minerals (the Kimberly Process and the International Conference on the Great Lakes Region) segues into a broader conversation about how central effective transnational and national governance is to these processes and to the human security issues that they in turn impact. Indeed, a repeated idea throughout the book is the impact, complexity, and context-specificity of good governance in its relation to the environmental conflict-migration nexus.

A standout chapter, "Environmental Migration Governance at the Regional Level," written by Federica Cristani, Elisa Fornalé, and Sandra Lavenex, explores the power that regional coalitions have in addressing the displacement of persons in the absence of comprehensive legal frameworks protective of vulnerable populations that cross international borders due to climate change-related factors. The authors present the fact of Latin America and the Caribbean as a region increasingly eager to engage in tackling environmentally induced migration, particularly in the aftermath of catastrophic events such as 1998's Hurricane Mitch and the 2010 Haiti Earthquake. The authors show how governments throughout the region have actively been creating actionable national and regional responses towards environmental refugees, with language specifically attributing forced migration to climate and the environment. This was a particularly interesting contrast to insights in Martin Geiger's chapter on global migration governance, which paints a different picture of hesitance at the international level towards related labels. Ultimately, while the region's idiosyncrasies (such as broadly shared linguistic and cultural ties) prevent it from being an extrapolatable example for other global communities, the authors provide a thoughtful review of what the beginning of promising work in this space might look like, especially when reinforced with greater coordination.

A reader looking exclusively to learn about definitive, causal links between climate change, migration, and the precise type of governance needed at this moment will not find that in this book. First, while climate change is widely discussed throughout the book, "environmental conflict" broadly encompasses a variety of environmental circumstances and events not necessarily attributable to climate change. Second, as the authors repeatedly demonstrate, the causes of environmental migration are complex and interrelated, and context is critical. Although the contributors provide impressively nuanced and often surprising dimensions to their respective field's understanding of the nexus, they are also eager to point out the multitude of gaps that remain to be researched.

The thought-provoking interdisciplinarity of *Environmental Conflicts, Migration and Governance*'s 12 chapters was likely due in no small part to the editors, who are all professors at the University of Freiburg, and whose expertise together provide myriad perspectives in conflict, migration, institutions, science, and policy. Krieger, a Professor of Constitutional Political Economy and Competition Policy, brings a research emphasis on institutions, factor mobility, and conflict. Panke, who is a

Professor of Political Science in addition to holding the chair for multilevel governance, provides a background in a range of subjects from comparative regionalism and international norms to small states in international relations. Pregernig, a Professor of Sustainability Governance, brings perspectives on sustainability, science, and society. The breadth and subject intersectionality of the editors and the authors reflect and contribute to this moment of humanity, where the dynamic nexus of the environment, conflict, and governance are breaking down disciplinary silos in order to drive better research and build better solutions.

What this novel collection of analyses and insights provides to readers is an important, evidence-driven, and directed start to a global conversation about what we currently know and what we critically need to be asking in order to inform immediately needed, impactful policies. The book provocatively closes with this sense of urgency, acknowledging that the evidence generated thus far is grounded in an understanding of ecological and social systems that may stand to be upended in the future by climate change itself.

Stephanie Martinez
*Behavioral Risk Research Coordinator, EcoHealth Alliance, New York, NY, USA*

World Medical and Health Policy



# Book Review

Ray, Sarah Jaquette. *A Field Guide to Climate Anxiety: How to Keep Your Cool on a Warming Planet. Berkeley, CA: University of California Press, 2020. pp. 207. ISBN: 978-0-520-34330-6*

The gargantuan proportions of current environmental crises all too easily overpower people who care about such crises. The problems may easily appear too big, too numerous, and too far removed from individual spheres of action. Especially as they map on and interrelate to a number of further equally fraught issues, such as social justice or its more specific constituents of race, colonialism, gender, and ableism. How to sustain power and enthusiasm for the challenges ahead? How to take on these interconnected struggles while avoiding burnout out or turn away frustrated from the frontlines? How to live well and thrive despite all existential grief about biodiversity loss and injustice? And will the planet notice? This marvelous book addresses these and related questions not in a spirit of scientific inquiry into the contours of climate anxiety, social justice, or resilience. Instead, it aims to provide clues, hints, and strategies. Its businesses are real-life tweaks and the cultivation of stances that enable one to stay strong and sustain capacities to engage in drawn-out struggles necessary to bring about change at the confluence of environmental care and social justice.

The combination of theoretical debate, biographical and fieldwork-based insights, assignments, and bullet point take-home messages at the end of each chapter situate the book halfway between textbook and toolkit. Across seven substantial chapters, the book engages pitfalls, risks, and limitations of climate activists in a bid to formulate ways out of the mess. Some of these risks are well known in the history of social movements, such as the risk of attempting to always be ready to fight (ableism) or to take on everything at once (overwhelm). And Ray convincingly mobilizes insights, tactics, and strategies from feminist or anti-racial struggles for the climate generation.

Key to these, Ray argues, is an embrace of slowness and knowing the sphere within which one wants to make a difference. Using a phrase of simple elegance, which is characteristic of the book, Ray (p. 67) encourages readers to "[s]low down, find stories of slow change, and cultivate slow hope." Alongside slow inquiry and



doi: 10.1002/wmh3.405

practice, Ray highlights the appeal of abundance to inform ethic, aesthetic, and political practice. Dwelling on abundance, she argues, helps to get over the language of "scarcity and sacrifice" (p. 118) that limits action, produces frustration, and ultimately runs against evidence. The ordinary routine of honoring abundance, she emphasizes, also calls attention to reciprocities among humans and across the human/non-human divide, thereby fueling the desire for different forms of interaction.

Thus conceived, slowness and abundance gesture toward individual efficacy that is at the heart of this book. Ray denies hope—as a sugary afterthought to gloomy visions—and bets on cultivating experiences of efficacy. Taking time, identifying suitable fields for action, picking your fight, engaging with colleagues, and cultivating care (instead of empathy) also across normative or ideological difference allows for a sense of efficacy to emerge that helps avoiding burnout and might lead the way to social transformation.

The strength of the book lies in revisiting the thought and practice of social movements and deploying such strategies to the cause of climate activism. This is a timely and urgent task given the ongoing environmental degradation and the resurging despair, on the one hand, and the increasing differentiation of the climate movement, on the other. In addition to providing tools of "how to keep your cool on a warming planet," as the title implies, the book also will be useful to pause and reflect on the next steps and to work against fissures and tensions within the climate movement itself. That being said, the book deserves a wide readership not only among students of social movements, ecology or psychology. It will benefit activists, students, and educators devising ways to counter the doom and thrive amidst ecological crises.

Arne Harms
*Max Planck Institute for Social Anthropology,*
*Halle, Germany*