Comment

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In June, residents in Portland, Oregon, fill a cooling centre to escape record-breaking temperatures.

Deploy heat officers, policies and metrics

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Cities need heat governance to plan for extreme temperatures and protect those most at risk.

In June, the blistering 'heat dome' that sat for weeks over western states of North America saw temperatures soar 20 °C higher than average in some places. Lytton, a village in British Columbia, reached 49.6 °C smashing Canada's previous national high, before the town was destroyed by a wildfire (see *Nature* **595**, 331–332; 2021). More than 1,000 people died from the heatwave across the region.

At the peak, more than 1,000 people a day in Oregon and Washington visited the emergency department for heat exhaustion and heat stroke, compared with 9 people in 2019. Some found relief in air-conditioned libraries and convention centres. Many – notably elderly people– couldn't reach these cooling centres. Out of the 54 excess deaths in Multnomah County, Oregon (peak temperature 46.7 °C), 80% were aged over 60. Most of those lived alone.

Governments were underprepared. The heatwave was forecast, but no-one 'owned' the problem. Heat is an outlier hazard – invisible, frequently chronic and subtly pervasive. Unlike for flooding or wildfire, no single organization or department is responsible for coordinating responses for extreme heat. Many residents don't have the resources to cope.

In fairness, heat is a complex hazard. It's more than air temperature — surface and radiant temperatures, air movement and humidity all influence the heat we feel. Urban areas are typically hotter than their surroundings (the urban heat island effect). But even in cities, a person's experience of heat can differ hugely from one block to another, or from a bench under a shady tree to one in full sun. Heat impacts depend on local contexts and inequities[1]. Everyone is at risk. Those who are marginalized, poor, young, old, homeless, institutionalized or have pre-existing medical conditions are affected most[2].

The impacts of extreme heat will intensify. Hot spells are becoming more frequent, intense, extensive and long-lasting as the climate warms. July 2021 was the hottest month ever recorded globally. Europe also saw record highs in August, when Sicily reportedly hit 48.8 °C.

A handful of places have taken action. This year, Miami-Dade County in Florida, and Athens, Greece, appointed the world's first two Chief Heat Officers; Phoenix, Arizona, created the first publicly funded Office of Heat Response and Mitigation. Much more remains to be done.

We call for a focused research programme to support 'heat governance' — including the actors, strategies, processes and institutions that can mitigate and manage this hazard. Institutions and policies need to be developed to address heat, across all levels of government. And that requires a strong evidence base.

Six principles

Decision-makers and researchers need to do the following.

Advance heat equity. Racism and income inequality affect people's ability to access health care, education, housing, energy and jobs, as well as to participate in government decision-making. All of those dictate outcomes of heat exposure. Lack of air conditioning in homes is an important predictor of illness and death from heat. Yet in 2017, 840 million people had no electricity supply. In some US cities, including Chicago and Detroit, white residents are more than twice as likely to have air conditioning as Black residents[3]. In Pakistan, only 5% of those with low incomes are projected to have indoor cooling by 2050, versus 38% of those with the highest income[4].

Humid heat is especially punishing. Several cities in Pakistan have already witnessed temperatures and humidity levels higher than the human body can survive — a threshold that climate models projected would happen beyond 2050 (ref. 5). Extreme humid heat has more than doubled in frequency since 1979.

Most analyses of heat vulnerability focus on identifying neighbourhoods most prone to hot temperatures, but heat risk is more nuanced. Researchers need to consider equity when examining how multiple risk factors converge, as well as when evaluating the trade-offs between different strategies to combat heat. For example, air conditioning generates greenhouse gas emissions; urban greening increases water consumption. Such downsides might be more acceptable in resource-poor districts, at least in the short term, than in wealthier areas, where residents can adapt more readily. Longer term, low-carbon indoor cooling and low-water urban shade should be prioritized.

Decision-makers must engage with communities to understand who heat affects the most, why and how best to deal with it. A good example is from the US National Integrated Heat Health Information System (NIHHIS), which was jointly developed by the Centers for Disease Control and Prevention (CDC) and the National Oceanic and Atmospheric Administration (NOAA). One NIHHIS project educated promotoras (community health workers) and maternal-health providers in the Juárez–El Paso binational US–Mexico region to improve heat health. Expectant mothers were given bilingual health materials to help them spot dehydration and the symptoms of heat stress.

> "Heat is an outlier hazard — invisible, frequently chronic and subtly pervasive."

Mitigate heat. Urban planners and designers have many strategies for cooling cities. They can shape land uses through planning and development regulations[6]. They might protect natural areas, plant trees, make hard surfaces more reflective, create spaces to encourage air flow, and minimize waste heat from air-conditioning units and vehicle exhausts. Researchers need to establish how effective these strategies are in different places and conditions, how they interact and their cumulative effects. Ventilation corridors, for example, have more impact relatively in dense cities with tall buildings, such as Hong Kong and Tokyo. Models suggest that reflective 'cool' roofs would reduce temperatures by 0.2 °C more in humid cities such as Florida, but by 1.2 °C more in drier cities such as California, compared with vegetated 'green' roofs[7].

Trade-offs need to be weighed. For example, in Los Angeles, a trial of a coating that makes pavements cooler by making them lighter succeeded in its stated goal[8]: it reduced land surface temperature (LST) by 4–6 °C. But, the reflected heat caused the mean radiant temperature (MRT) above the paving to rise by 4 °C at midday, relative to untreated asphalt. In another example, one model of urban greening in Phoenix showed that a 20% increase in vegetation would cool the city, but at the expense of almost a 33% rise in water use[9].

Heat mitigation also needs to be targeted at areas used by higher-risk groups. That means focusing urban greening on districts with the least amount of vegetation, often the poorest, rather than leafier suburbs. Shade should be increased in public places with most footfall, such as transit hubs and shopping districts, linked by cool corridors for pedestrians and cyclists.

Manage risks. Governments can also call on a range of strategies for managing heat. These include: early-warning systems, public-health campaigns, policies to protect outdoor workers and programmes to make indoor cooling and energy more affordable and accessible. Researchers need to establish the effectiveness of each strategy and how efficacy varies between population groups.

For example, few studies have evaluated early-warning systems for extreme heat, despite some having been run for decades. In Baltimore, Maryland, since 2006, the Health Commissioner has issued a Code Red Extreme Heat Alert when air temperature exceeds 40.6 °C. Text messages are sent out, media outlets relay information and cooling centres open. Ahmedabad in India adopted a Heat Action Plan in 2013 after a heatwave in 2010 killed more than 1,300 people. The plan, updated in 2019, includes workshops to build public awareness, multilingual media announcements, an early-warning system and training for health-care professionals. Such systems should be continually evaluated; Ahmedabad's is reviewed every year.

Management must also be broadened to address chronic heat. For example, from 2015 to 2019 in Maricopa County, Arizona, only 23% of heat-associated deaths occurred on days with a heat warning. In tropical and subtropical climates, high temperatures and humidity can persist for months[10]. The rate of school learning decreases as the number of hot days increases[11].

Develop metrics. Measures that assess progress towards heat mitigation and management goals need to be agreed on and collected consistently. For example, public-health officials might focus on preventing heat-related illness and death, whereas urban planners might measure success by reducing neighbourhood temperatures. Governments need a range of metrics that span scales and sectors.

Conflating different types of heat is one problem. Urban heat islands are typically measured using LST derived from satellite imagery. Thermal exposure for people is often measured in terms of MRT, which combines several factors such as humidity, wind and radiant heat. As the Los Angeles cool pavement study showed, interventions that reduce LST might make MRT worse.

Researchers must advise decision-makers about what levels of temperature are appropriate for goals and mitigation strategies. Social impacts, time of day and season must

SAM PANTHAKY/AFP/GETTY

People in Ahmedabad, India, drink buttermilk to cool down in a 2019 heatwave.

be considered. For instance, the urban heat island effect is often strongest at night and early morning, but increasing daytime shade might be more impactful from a public-health perspective.

Although the number of visits to cooling centres is sometimes logged, the effectiveness of these facilities in preventing illness and death is rarely measured. Cooling centres are often open only during the day, not at night, and heat can prevent sleep and body recovery. They're usually closed outside 'official' heatwave periods, even if high temperatures persist.

Climate-change reports often focus on average global temperatures, but even a small change in average temperatures will lead to a large increase in the number of days with extreme heat. For example, climate models suggest that an increase from 1.5 °C to 2 °C would almost triple the percentage of the global population exposed to severe heatwaves at least every 5 years, from 14% to 37% (ref. 12).

Heat metrics are often reported inconsistently. Mortality estimates differ across local and national counts, and are lower than those derived statistically based on excess mortality. Heat often kills indirectly and some deaths, such as a heart attack induced by heat, might not be listed on coroner reports. Although 37% of heat-related deaths globally have been attributed to global warming caused by humans, empirical data are lacking in the global south, an area of high concern for temperature increases[10].

Coordinate initiatives. Dedicated city roles, processes and organizational structures are needed for heat governance. These must span: urban planning, public health, emergency management, housing, infrastructure, financing, health care and energy. Research examining which systems govern heat most effectively would help cities to learn from each other.

Local community plans and policies should be integrated to avoid conflicting goals. For example, a plan might call for more retail or housing development to generate sales tax revenue, but the associated parking, road expansion and vegetation removal will raise local temperatures. A positive example is the Cool Neighborhoods New York City report, which includes shared goals on heat mitigation and management strategies, such as tree planting, reflective roofs and development of buddy systems for vulnerable residents.

Heat also spans jurisdictional boundaries, requiring coordination at a regional level. One example of good practice is the Western Sydney Regional Organisation of Councils in Australia. Its 2018 the Turn Down the Heat plan includes mitigation and management strategies with input from 13 municipalities, the private sector, universities and non-governmental organizations.

Build heat institutions. National governments should address the large, inequitable and growing consequences of heat risks. Doing so can have immediate benefits. For instance, France's National Heatwave Plan, implemented after the 2003 heatwave which killed 15,000 people, saved more than 4,000 lives in 2006. It features a warning system, check-ins for vulnerable residents, air conditioners for retirement homes and more.

National programmes should be set up to coordinate fragmented efforts. In the United States, NOAA administers heat warnings, the Environmental Protection Agency offers heat mitigation guidance, and the CDC provides public-health information and tracks heat-related illnesses. To draw together such efforts, the NIHHIS was set up as an interagency working group and community of practice with municipal decision-makers. Yet it still lacks official authority and capacity. National governments should support similar initiatives.

Regulatory and policy gaps need to be plugged. As with regulations for air and water pollution, limits should be placed on heat produced by the built environment. 'Cool communities standards' should be adopted that integrate heat mitigation strategies into development and building regulations. Governments should borrow best practices from similar domains such as flood governance, where developers must address flood risks for new buildings.

New roles, processes, strategies and institutions must be evaluated. Heat governance insights should be shared internationally, for instance through the Global Heat Health Information Network, organized by the World Health Organization and the World Meteorological Organization (see https://ghhin.org). Its forum is a good opportunity for practitioners and researchers to build heat governance capacity from local to global levels.

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