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"Silent Killer: The Rising Problem of Extreme Heat in the U.S."
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Good morning Chairwoman Johnson, Ranking Member Lucas, and members of the House Committee on Science, Space and Technology. Thank you for inviting me to highlight a serious, growing problem that has resulted in preventable deaths and illnesses. My name is Melissa Guardaro and I am an urban heat researcher focusing on adaptive capacity, governance, and equity. I work at Arizona State University at the Healthy Urban Environment initiative, an urban heat and air quality innovation incubator, and at the Knowledge Exchange for Resilience, a network of collaborators and community partners working to share data and knowledge to improve community resilience. I am bringing testimony deeply informed by working in and learning from communities located in the nation's hottest large metropolitan area, Phoenix, Arizona. We are on the frontlines for extreme heat and are an important testbed for learning how to adapt to a warming climate.

Extreme heat = climate change + urban heat islands

There is a growing threat in cities, escalating costs, killing people, yet is invisible: extreme heat. Extreme heat is a multidimensional problem impacted by two different, yet similar, issues: the urban heat island effect and climate change. Municipalities within the United States have varying levels of policies to combat urban heat and regional approaches to extreme heat are in the nascent stages.

The urban heat island comprises many different microclimates that reflect the difference in vegetation, urban form, and ground cover. Heat is retained during the day by roads, buildings and other built structures and released slowly at night resulting in elevated nighttime temperatures within the urban core compared to surrounding rural areas (Aggarwal et al, 2012). Other contributing factors include waste heat from buildings, industry and transportation, and the urban form. Depending upon the size and shape of a city, the urban heat island effect has been measured between 4° and 22° F (Oke, 1987). This is harmful over the long term and affects water use, air quality, thermal comfort, public health and energy demand (Vargo et al, 2016).

While the urban heat island effect is a product of urbanization, extreme heat is amplified by climate change. According to the Fourth National Climate Assessment, average temperatures

have been increasing steadily and summer heat waves will be longer and hotter. To provide context, the National Weather Service reports that in 2020, metropolitan Phoenix experienced 145 days over 100ºF and 53 days over 110ºF. In developing policies and programs, it is important to address both the urban heat island effect and climate change together in a systemic manner since the thermal environment is about more than reducing air temperatures. Increasing shade may have a small impact on air temperatures but a huge impact on thermal comfort, health and infrastructure performance (Middel, 2016). The principal concern is how people experience heat as they move through their day and their thermal comfort.

According to the Environmental Protection Agency (EPA), strategies for reducing urban heat islands include increasing trees and vegetation, installing green and cool roofs, using cooler materials on paved surfaces, and implementing smart growth strategies (EPA, n.d.). Climate change reduction strategies include greenhouse gas emissions reductions, transitions to non-carbon energy sources, energy conservation, and energy efficiency measures such as weatherization programs. There are cases where these strategies are mutually supportive: tree planting programs on public transit access routes not only reduce the urban heat island effect but also lead to more public transit use, reducing private vehicle use and thereby reducing waste heat and greenhouse gas emissions.

Further, extreme heat needs to be addressed in two different timescales – policies and programs that constrain a warming future and urgent action to protect people when extreme heat occurs today. The main objective of an emergency response to extreme heat events is to immediately provide more cooling for people. Heat relief emergency plans along with access to cooling centers and cool spaces are an effort to alleviate suffering and avert catastrophes. Utility assistance programs, such as LIHEAP, and moratoriums on evictions help to keep people in their homes with cooling devices running. Education and outreach programs highlight the dangers of extreme heat, warning signs for serious illness, and provide strategies to keep safe during extreme heat.

Long-term strategies to build heat resilience in communities will help to lessen the impact of extreme heat by building a cooler environment. Intervention points include infrastructure, buildings, urban forestry, regional collaborations and city management. Green infrastructure not only provides cooling to adjacent areas but also mitigates stormwater runoff. Transportation systems can prioritize cooling routes to public transit nodes and reduce waiting times. Regionally, cool corridors provide thermal comfort and promote active transportation. Better urban design increases air flow, reduces thermal gain, and provides shade at the street level. Green building codes encourage more energy efficient buildings and promote the use of materials that absorb less heat. Urban forestry and vegetation, managed strategically, provide equitable access to parks and cool streetscapes.

These resilience building strategies also require social infrastructure to ensure there is community buy-in and political will to implement evidence-based interventions in a timely manner. Funding of regional collaborations across jurisdictions to tackle extreme heat allows for a coordinated response that builds commitment to regional cooling utilities or regulations that

curtail carbon-intensive and heat-trapping infrastructure projects. The Arizona Heat Preparedness and Resilience Workgroup, originally formulated to tackle extreme heat during the COVID-19 pandemic, has expanded from coordinating emergency responses, such as sharing best practices in operating cooling centers during a pandemic to collaborating on long-term heat resilience solutions with municipalities, public health departments, academia, the faith community and non-profits (Guardaro et al, 2021). City management devoted exclusively to managing extreme heat, as in the Miami, Florida Chief Heat Officer and the City of Phoenix Office of Heat Management and Response, are good first steps.

Urban heat is an equity issue

Extreme heat is not experienced equally within cities. The urban heat island effect is an equity issue for historically marginalized neighborhoods. Research has shown neighborhoods that are in redlined areas have less infrastructure investment, little vegetation, and fewer trees resulting in hotter neighborhoods (Miller, 2021; Hoffman, 2020). Affluent white neighborhoods had summer temperatures as much as 13F cooler than in low-income Latino neighborhoods. Further, poorer neighborhoods lacked resources such as cooling centers and parks to help residents cope with extreme heat (Harlan, 2017).

Increased exposure to extreme heat is linked to housing issues, resulting in a lack of adequate shelter from the elements. Residents in low-income neighborhoods live in housing that is often energy inefficient with aging cooling systems. These residents are challenged by energy insecurity as a greater proportion of their incomes are spent on electricity. Mobile home residents are especially vulnerable as they may not qualify for utility assistance, live on fixed incomes, and have very limited shading infrastructure. A recent study by the Knowledge Exchange for Resilience revealed that in Maricopa County, Arizona, mobile homes comprised 5% of the housing stock, yet accounted for 28% of heat deaths in 2019 (Phillips, 2020). In 2020, during the pandemic when a moratorium was in place for evictions and utility disconnections, those individuals experiencing homelessness are less than 0.17% of the population and accounted for 53% of heat associated deaths (MCDPH, 2021). Affordable, livable housing is a critical factor for heat-health safety.

Local scale and community engagement

Extreme heat intensity depends heavily on local landscape characteristics such as amount of vegetation, paved surfaces, open space, housing quality, and building density. It is imperative to include community perspectives in designing and implementing extreme heat solutions. While poor and marginalized groups historically have suffered the most from climate impacts, they are often left out of the climate planning process, and some adaptation efforts may exacerbate existing inequalities (Guardaro, 2020). Meaningful participation, especially of communities of color, can increase local adaptive capacity and agency, and reveal strategies that are culturally relevant and appropriate to the local context.

The Nature's Cooling Systems project was implemented in three underserved neighborhoods in metropolitan Phoenix to develop hyper-local community heat action plans (Messerschmidt, 2019). This inclusive, storytelling-based planning process revealed differing needs and wants between communities despite relatively similar socio-economic profiles. For example, shade was prioritized along routes to school in two communities and on paths to transit nodes in another. For one community, increasing shade meant increasing the tree canopy; for the other two communities shade could be from trees, structures, buildings, or artwork. Urban planners, applying a one size fits all approach, would have missed these resident concerns.

Urban heat expertise comes in many forms, one of which is the lived experience of residents in the hottest neighborhoods. Asset maps of the coolest and hottest locations in the neighborhood revealed strategic opportunities not discovered through quantitative data. Residents of one neighborhood in the Nature's Cooling System project pointed to a bus stop location that needed shading, baffling the team experts as there was no public transit stop at that location. Instead, it was a heavily used *school* bus stop, prompting a larger discussion about the importance of shading schoolkids and those who wait for the school bus with them.

Local initiatives can have an outsized impact. Resilience hubs, collaboratively developed with grassroots organizations, empower vulnerable groups and are levers to lessen social justice and manage resilience transitions. According to the Urban Sustainability Directors Network (USDN), resilience hubs are community-serving facilities augmented to support residents, coordinate communication, distribute resources, and reduce carbon pollution while enhancing quality of life. Resilience Hubs are located in a trusted physical space, operate 99% of the time in normal mode, but can spring into action during disruptions and recovery. These hubs are useful during extreme heat events by acting as a cooling center, disseminating heat health and weather communications, and promoting community cohesiveness by checking in on neighbors. During non-emergency situations, resilience hubs can be the central force in advocating for community resilience and cooling solutions that provide greater thermal comfort and reduce thermal injustice. This concept, originating in Baltimore, Maryland, is being developed in Miami, Florida, Tempe, Arizona and Mesa, Arizona and other locations.

Federal investments

Federal investments are needed to prepare urban communities for extreme heat and to assist in the mitigation and adaptation to a warmer future. NOAA and EPA can play central roles in supporting research, promoting policy, and developing products that will contribute to better decision making. Many Federal agencies can play a supporting role including FEMA, NSF, NIH and the Departments of Transportation, Commerce, and Housing and Urban Development. My colleagues have seen early glimpses of what is possible with Federally coordinated investments in heat through the National Integrated Heat Health Information System (NIHHIS) capacity building borderlands project in El Paso/Juarez. Participating agencies for this project include CDC, EPA, FEMA, NIOSH, NOAA, OSHA, ASPR and SAMHSA. Coordination with

governments at multiple scales (national, regional, state, city) will catalyze solutions and reduce competing commitments.

NOAA/NWS Extreme Heat Center

Similar to the Storm Prediction Center, a **NOAA/NWS Extreme Heat Center** is needed to coordinate national efforts to understand and respond to the impacts of extreme heat. More outreach and education are needed to communicate why some states issue heat warnings regularly for extreme weather and others rarely. One gap in understanding that would benefit from more research is how heat health safety information and weather products are consumed, by whom, and how to effectively design them. Utilizing social scientists at the proposed Extreme Heat Center could help determine how to make more usable and effective products. The planned NOAA Climate/Equity Roundtable on Heat Risk could become a regular activity to support this effort. Other important priorities could be:

- Evaluation studies to understand what is effective to protect people from heat, building on pilot studies completed with CRSCI/BRACE investments
- Capacity building for monitoring heat conditions in dangerous settings like outdoor workplaces, indoor non-air-conditioned workplaces, athletic competitions, and implementing safety measures and responses
- Understanding the cost/benefit ratio of various heat mitigation actions
- Translating academic research into useful consumer information products
- Capacity building at the municipal scale
- Coordination of multi-sector heat data

Just as there are National Weather Service StormReady communities, NOAA can support the scaling up of the Healthy Urban Environments funded HeatReady Cities program. This program is being piloted in metropolitan Phoenix and provides an evaluation tool to holistically manage how they identify, prepare for, mitigate, track, and respond to the dangers of urban heat. HeatReady Cities are those who have identified personnel specifically tasked with urban heat management, have programs for extreme heat emergencies, and are planning heat resilience strategies in the short and long term. Pilot projects are underway to extend the HeatReady concept to HeatReady Schools and HeatReady Neighborhoods, all of which could be national programs supported by the Extreme Heat Center.

Regional coordination

There is a great need for coordination across jurisdictions for data development, working groups, pilot projects, and funding mechanisms. The EPA, NIHHIS, or the proposed Extreme Heat Center could provide a critical role in providing the social infrastructure, policies, and funding to ensure that a regional, not the competitive city-by-city approach of today, is undertaken.

Regional data is vital for decision making at various scales. A regional heat data website for landscape level, socioeconomic and public health statistics is needed that also includes equity

data, co-created community-based data, and people centered climate measurement data such as mean radiant temperature. This information can be used across regions to support regional decision making and coordinated planning for regional heat resilience.

An expansion of the current EPA Environmental Justice Small Grants program, specifically focused on extreme heat mitigation would support local, community-based efforts and address equity and environmental justice issues by the communities that have been most impacted by urban heat. These pilot projects could be scaled up and adapted for other regions, creating a toolkit of grassroots urban heat solutions.

Using the current EPA regions, working groups could be established to develop regional approaches to extreme heat emergencies and to build regional resilience to heat. Municipalities, academic institutions, health departments, non-profits, and businesses could use the working groups not only to develop solutions but also to develop critical social infrastructure, a necessarily but often overlooked component in building momentum for transformational change. Capitalizing on existing government-university-community relationships, the EPA could accelerate coordination between contiguous jurisdictions and overcome the problem of "shopping" for areas with few regulations. The regional working groups could develop regional cooling utilities that support green infrastructure, cool material usage, cool corridors, cooling centers and resilience hubs, catalyzing long-term local funding.

Heat and health data surveillance

Public health is impacted by extreme heat and results in preventable deaths and illnesses at great economic costs. During the late June 2021 heat wave in the Pacific Northwest, the death toll is projected to be over 200 people, in what is now being labeled a mass casualty event (Bekiempis, 2021). Heat-associated deaths by year are steadily increasing in metropolitan Phoenix, culminating in 323 deaths in 2020, an increase of 62% from the prior year (MCDPH, 2021).

It is difficult to understand the human cost of these increasingly common heat emergencies without additional efforts towards tracking heat deaths. Differences of method in how heat deaths are counted and reported lead to inconsistencies in data that make heat safety planning and response difficult (Johnson et al 2016; Harduar Morano and Watkins 2017). Differing methods of counting heat deaths mean that, while the CDC reports approximately 618 people per year are killed by heat in the United States (CDC 2021), the National Oceanic and Atmospheric Administration reports less than 150 (NOAA, 2021). Meanwhile, in Arizona, where a more comprehensive heat-health surveillance is an established practice, more than 500 deaths were reported in 2020 alone (ADHS 2021).

These discrepancies indicate that we are underestimating the scale of suffering due to extreme heat and undercounting the cost to economic development, human health, and quality of life at the national scale. As more US cities experience unprecedented extreme heat, we must motivate federal, state, and local partners to begin tracking heat as a silent killer using the best practices science can offer. In the largest county in Arizona, Maricopa County 's Department of

Public Health and Office of the Medical Examiner offer a model for other jurisdictions who are facing the grim reality of heat-related deaths. Through close partnerships with academics and public health officials, the county continuously surveils deaths throughout the summer. From the first moment a death investigator from the medical examiner arrives on the scene of a death from unknown causes, heat is on their mind. They are equipped with checklists that document the temperature, whether the deceased had air conditioning, if they had access to outdoor shade, and other relevant environmental details. In combination with certain physiological signs during an autopsy, these reports are used to determine if heat was a contributing factor to the person's demise. The medical examiner continuously reports heat death statistics to the county's health department, which analyzes the preliminary data to understand who is dying from heat. Information shared goes far beyond the cause of death to include the person's housing status, access to electricity, and the conditions leading up to their death. The public health department discusses these data with community and government partners throughout the year so that as the heat closes in every summer, we are preparing and planning to keep residents safe rather than scrambling to react to surprises. A similar program across jurisdictions and geographies - a program that not only investigates heat deaths but shares the data with stakeholders - must be the bedrock of any effective heat safety action.

Intersectionality

More research is needed to better understand the intersectionality of extreme heat with other issues such as housing, health care access, mental health and drug addiction. Climate is not the only factor that determines how many people will be impacted by extreme heat. Underlying weaknesses are exposed and increase heat-vulnerability during extreme heat periods (Putnam, 2018). Often the most heat-vulnerable are faced with two bad choices: pay for air conditioning or pay for rent, for example. While there is ongoing research on thermal properties of materials, urban design, landscaping and cooling corridors, the human impacts of extreme heat, and modeling of interventions such as shade trees, more research is needed on how cooling elements work together to produce a more thermally comfortable environment and the efficacy of interventions in differing geographic regions and urban contexts. Improved coordination between Federal science agencies and other stakeholders would improve heat-related responsiveness and proactivity.

A research program that provides greater understanding of the economic impact of extreme heat would help to build the business case for extreme heat resilience investments. In Arizona, over a ten-year period, extreme heat health costs were estimated to be $17.8 billion. While the CDC has estimated the health costs of heat including loss of life, studies that also include infrastructure damage due to increasing heat, business losses, and reduced productivity would build an argument for transformational investments. The Departments of Transportation, Interior, Commerce, and Housing and Urban Development could all contribute to a better grasp of total economic impact and levers for change.

Coordination between EPA, NOAA and FEMA to recognize extreme heat as a disaster could provide better prioritization of both emergency response and long-term mitigation and adaptation efforts. These three agencies can work together to reverse thermal injustice and keep residents safe during and after extreme heat periods by developing systems driven solution pathways. The National Science Foundation could help support the NOAA Extreme Heat Centers by funding empirical research on heat-reducing innovations across regions. The National Institute of Health could likewise assist in this effort by supporting heat-health and treatment research.

We need to act now to provide more thermal comfort during extreme heat events for the most vulnerable populations and to tackle extreme heat in a systemic manner, acknowledging the interconnected nature of extreme heat contributing factors. Increased federal funding for more research, equitable policy formulation, and implementation of cooling strategies will avert unnecessary heat deaths and illnesses. Arizona State University, a top ranked university for urban heat research, is a ready partner for continued Federal heat work with fifteen centers and programs focusing on extreme heat initiatives. Thank you again for giving me the opportunity to testify and to contribute to the efforts to address the growing problem of extreme heat.

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