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PAS REPORT 600

PLANNING FOR URBAN HEAT RESILIENCE

Ladd Keith, PHD, and Sara Meerow, PHD

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ON THE COVER

The Brown Foundation Promenade is a limestone path shaded by majestic 100-year-old oak trees that forms the heart of Discovery Green, a 12-acre park in downtown Houston. Remnants of an early residential neighborhood, the trees were surrounded by concrete parking lots until Houston philanthropists led the creation of a transformative public park, which opened in 2008 (photo courtesy of Katya Horner)

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ABOUT THE AUTHORS

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Sara Meerow, PHD, is an assistant professor in the School of Geographical Sciences and Urban Planning at Arizona State University. She is an interdisciplinary scholar who works at the intersection of urban planning and geography to tackle the challenge of making cities more resilient to climate change and other social and environmental hazards in a way that is sustainable and just. Her current research focuses on conceptualizations of urban resilience, climate change adaptation, and green infrastructure planning in a range of cities across the U.S. and internationally. To date she has published 30 articles in academic journals, in addition to several book chapters, reports, and popular press articles on these topics. She has a PhD in Natural Resources and Environment from the University of Michigan and an MS in International Development Studies from the University of Amsterdam.

TABLE OF CONTENTS

PREFACE

Human thermal comfort is one of the most important issues for planners to address as communities across the United States continue to get hotter. We live in cities where two neighborhoods, mere miles apart, can differ in temperature by 20 degrees Fahrenheit. What may be an enjoyable jog in one neighborhood can be a dangerous endeavor in another, where the streets and buildings become heat sources that push us beyond our heat tolerance limits.

The urban spaces we live in today were shaped by centuries of precedent and decades of plans and policies from past generations. The plans we make now will set precedents for future generations. We have inherited many cities that are safer and more sanitary than in the past, but that were also shaped by exclusionary zoning laws and a lack of understanding for how some types of development can create unfavorable microclimates for us to live, work, and play in. As the effects of climate change are already being felt, we must urgently plan our cities to better support equitable human thermal comfort in communities today and in the future. This critical text shows us how.

This report is an essential addition to the literature enabling urban and regional planners, and their partners, to create the future cities we need to thrive—cities that are resilient to climate change and cities where everybody has an equitable say in our future. The National Oceanic and Atmospheric Administration (NOAA) Climate Program Office and the interagency National Integrated Heat Health Information System (NIHHIS) are excited to partner with the American Planning Association in this effort to apply the best research, information, and ideas to improving our urban spaces and increasing urban heat resilience.

Hunter Jones
Extreme Heat Risk Initiative Program Manager
National Integrated Heat Health Information System
National Oceanic and Atmospheric Administration

Urban Heat Resilience

Heat is the #1 weather-related killer in the United States

PAS Report 600 shows how to integrate heat mitigation and management strategies into local planning to create more heat-resilient communities.

Climate Change

Average annual temperatures in the US have risen by
1.8°F (1°C)
since 1900
(USGCRP 2018)

Latest IPCC report states that models suggest a
16 to 36 fold
increase in heatwave exposure by 2100
(IPCC 2022)

Annual average temperatures in the US are projected to increase between
3°F (1.7°C) and 12°F (6.7°C)
by 2100 depending on emissions
(USGCRP 2018)

Urban Heat Island Effect

The urban heat island (UHI) effect causes urban areas to be as much as
7.2°F (4°C) hotter during the day
and 4.5°F (2.5°C) hotter at night
(Hibbard, Hoffman, Huntzinger, & West 2017)

Formerly redlined neighborhoods are an average of
5°F (2.8°C) hotter
in the summer, up to as much as 12°F (6.7°C) in some cities
(Hoffman, Shandas, & Pendleton 2020)

Solutions

Heat mitigation
Reducing the built environment's contribution to urban heat

+

Heat management
Preparing and responding to chronic and acute heat risk

=

Heat-resilient communities

EXECUTIVE SUMMARY

In the summer of 2021, record-breaking extreme heat events struck communities across the world. The unprecedented U.S. Pacific Northwest and Western Canadian heat wave took communities by surprise. Records were broken across the region, from larger cities such as Portland, Seattle, and Vancouver to smaller towns like Lytton in British Columbia. Lytton hit 121°F (49.5°C), the highest temperature ever recorded in Canada, and then tragically, was destroyed when a wildfire swept through the drought and heat-stressed forest a few days later. Record-breaking heat waves also struck historically hotter climates like the U.S. Southwest, where records were broken in cities such as Los Angeles, Las Vegas, Phoenix, and Tucson.

As average global temperatures rise, heat is increasing. This includes the frequency, length, and intensity of extreme heat events, such as heat waves, and the threat of chronic heat. Heat is already the number one weather-related killer in the United States, and heat impacts are projected to increase as temperatures continue to rise. While extreme heat events are dangerous everywhere, in climates that are already hot, chronic hot temperatures are an equally dangerous threat, often leading to more heat deaths than recognized extreme heat events.

Heat also affects communities' quality of life, local economic activity, energy and water use, wildlife, vegetation and landscaping, infrastructure, and agriculture. These negative consequences disproportionately affect marginalized residents and those who face systematic inequities such as workplace safety, housing quality, energy affordability, transportation reliability, and healthcare access.

Both climate change and the urban heat island (UHI) effect, in which the form and function of the built environment make urban areas hotter than their rural and natural surroundings, are contributing to these rising heat risks. The way communities are planned, including land uses that shape the built environment, influences both the emission of greenhouse gases that create climate change and the UHI effect. Because planning shapes heat risk, and the profession has a responsibility to foster equity and inclusion, planners will be key practitioners in helping their communities pursue approaches and strategies to achieve greater heat resiliency.

Urban heat resilience means proactively mitigating and managing urban heat across the many systems and sectors it affects. This PAS Report, *Planning for Urban Heat Resilience*, seeks to elevate heat as a climate risk in the urban planning profession. The report lays out the complexity of heat, outlines the role of planners in equitably addressing heat, and presents a framework for how planners can mitigate and manage heat across a variety of plans, policies, and actions.

AN INCREASING, INVISIBLE, AND INEQUITABLE CLIMATE RISK

Hotter temperatures are impacting communities of all sizes and in all regions. Increases in both chronic and acute heat risks are compounding dangers for cities in historically hotter regions and posing new threats for cities in historically more temperate and colder climates. Cities in historically colder regions are often less prepared for heat, as they have lower adoption rates of indoor cooling and less experience managing extreme heat events. In areas with higher humidity, even small temperature increases can increase the danger to human health.

While communities everywhere are getting hotter, heat risks are unevenly and inequitably distributed. This report explains why some neighborhoods are consistently hotter than others, including districts with a history of redlining or communities of mostly low-income or minority residents. Past planning decisions played a role in creating and furthering these disparities. Certain community members are also more vulnerable to heat-related illness or death; these include children and the elderly, people with chronic health conditions or lower incomes, people experiencing homelessness, and people who are institutionalized.

Communities must prepare for increasing heat and address systemic inequities in heat risk. This report makes the case that planners are well suited to take a leading role in advancing urban heat resilience in their communities through equitable distribution of efforts, recognition of historical injustices and diverse needs of their community, and procedures such as inclusive public participation.

A FRAMEWORK FOR URBAN HEAT RESILIENCE PLANNING

Planners seeking to increase their communities' urban heat resilience can equitably prepare for and adapt to both chronic and acute heat risk through heat mitigation and management strategies. This PAS Report lays out a framework for addressing urban heat, which requires setting clear urban heat planning goals and developing associated metrics for success; building a comprehensive "fact base" of information on heat risks; developing a diverse portfolio of heat mitigation and management strategies; managing uncertainty; coordinating across planning efforts; ensuring inclusive participation in planning processes; and effectively implementing, monitoring, and evaluating urban heat resilience efforts.

Addressing a challenge such as heat starts with understanding the issues. This report gives planners a baseline grounding in the science behind extreme heat and the various ways it can be experienced, measured, and tracked. It rounds up data sources and analytical tools for measuring heat's impacts on communities. With this foundation in place, planners can pursue heat resilience through the dual approaches of heat mitigation and heat management.

Heat mitigation strategies aim to reduce the built environment's contribution to urban heat. While many communities are pursuing urban greening strategies, such as urban forestry and green stormwater infrastructure, to mitigate heat, a broader set of heat mitigation tools are available to planners. This report discusses heat mitigation approaches in the areas of land use, urban design, urban greening, and waste heat reduction, and it offers planners guidance on integrating heat mitigation into community visioning and engagement, plans and policies, regulations and project reviews, and public investments.

Heat management strategies are those that prepare for and respond to chronic and acute heat risk. Similarly, many communities are establishing cooling centers and early warning systems to help manage extreme heat risk, but they are leaving additional tools that better address chronic heat and systematic inequities on the table, such as ensuring access to reliable energy and indoor cooling, reductions in personal heat exposure, public health measures, and emergency management planning and response. This report explains how planners can coordinate with allied professionals on these heat management strategies to ensure community members have quality housing, indoor cooling, accessible and reliable energy, and safe and dependable transportation options.

Urban heat resilience requires effective coordination between different disciplines and sectors, such as hazard mitigation planning, public health, emergency management, the energy sector, and various levels of government. Planners should develop a diverse portfolio of heat mitigation and management strategies. These heat resilience strategies should be prioritized to maximize co-benefits, minimize tradeoffs, and avoid maladaptive strategies that provide short-term relief but worsen the problem in the long run (e.g., highly inefficient air conditioners that increase electricity demand and greenhouse gas emissions). Because heat resilience strategies will likely be needed across a variety of community plans, the report highlights for planners the importance of coordinating and integrating all plans and policies to advance the community's vision for heat resilience.

A CALL TO ACTION

Heat poses a growing and inequitable threat. Cities around the world must plan now to increase urban heat resilience in the face of climate change and the UHI effect.

Planners are well positioned to use existing regulatory tools and plans to mitigate the inequitably distributed risk associated with the UHI effect, reduce greenhouse gas emissions contributing to climate change, and help prepare for extreme heat events. This PAS Report equips planners with the background knowledge, planning framework, and catalog of comprehensive approaches to heat mitigation and management they need to work effectively with colleagues across agencies and sectors and advance urban heat resilience in their communities.

CHAPTER 1

URBAN HEAT: A GROWING RISK

Across the world, urban areas everywhere are getting hotter. Rising temperatures and more frequent, intense, and longer-lasting heat waves are a growing threat to public health, economies, infrastructure, and ecosystems.

Extreme heat is an increasing climate risk for communities around the globe due to both the urban heat island (UHI) effect and climate change. In many urban areas, the buildings, roads, and paved surfaces of the built environment absorb and re-emit the sun's heat more than natural areas and open space. This, along with waste heat, results in "heat islands" of higher temperatures relative to surrounding areas. The UHI effect causes temperatures to be as much as 7.2°F (4°C) higher during the day and 4.5°F (2.5°C) higher at night than in surrounding areas (Hibbard et al. 2017) due to the concentration of structures in the built environment and mechanical operations that produce waste heat (Figure 1.1).

Climate change is exacerbating the UHI effect. Average annual temperatures within the contiguous United States have already risen by 1.8°F (1°C) since 1900, and are projected to rise by 12°F (6.7°C) by 2100 if greenhouse gas emissions continue at their current pace (Hayhoe et al. 2018). In addition to increasing average annual temperatures, climate change is also increasing the frequency, duration, season, and intensity of extreme heat events, also known as heat waves (U.S. EPA 2021a).

Figure 1.1. While extreme heat is a growing concern in communities worldwide, cities such as Los Angeles have the added risk of urban heat from the built environment and waste heat (ChrisGold/Flickr (CC BY-NC 2.0))

While other climate risks such as sea level rise, flooding, drought, and wildfires have garnered more media attention and planning efforts to date, extreme heat is already the deadliest of all climate risks in the United States. Extreme heat exposure varies based on geography, climate, and built environment, with communities in warmer climates facing increased temperatures and many communities in cooler climates moving into new heat thresholds. It poses a growing threat to communities' social, economic, and environmental well-being.

Extreme heat is a complex hazard that presents risks both acute (sudden and dramatic) and chronic (slowly unfolding and often unnoticed). During an extreme heat event, such as a heat wave, heat risks become acute, and disastrous outcomes must be prevented through the planning, preparation, and implementation of heat management strategies.

Past extreme heat events have had deadly consequences, with the tragic 1995 Chicago heat wave resulting in more than 700 deaths primarily concentrated in the city's low-income and marginalized areas (Davis et al. 2003; Klinenberg 2015). Over 70,000 deaths were attributed to the 2003 European heat wave (Robine et al. 2008) and 55,736 deaths were attributed to the 2010 Russian heat wave (Centre for Research on the Epidemiology of Disasters 2011). More recently, over 1,000 people died as a result of the record-breaking 2021 heat wave in the U.S. Pacific Northwest and Canada, as

2021 HEAT WAVES BREAK NORTH AMERICAN RECORDS

In the summer of 2021, a record-breaking heat dome occurred over the U.S. Pacific Northwest and Western Canada (Figure 1.2). While weather services accurately forecast the heat wave weeks in advance, local, state, and national governments—as often is the case—were largely unprepared to respond to the unprecedented extreme temperatures.

Between June 26 and 29, daytime high temperatures exceeded 100°F (37.8°C), breaking records across the region. Portland, Oregon, set all-time records for three days, with temperatures reaching as high as 116°F (46.7°C). Seattle also broke all-time records for three days, peaking at 108°F (42.2°C). Lytton, British Columbia, reached 116°F (46.7°C) on June 27, which set a national record for Canada, but this record was broken the next day by another record temperature of 121°F (49.4°C) (Di Liberto 2021). To put this into perspective, the record high temperature for Las Vegas is currently 117°F (47.2°C).

This extreme heat wave detrimentally affected communities across the region. In addition to the record-breaking daytime temperatures, nighttime temperatures also exceeded health and safety levels, giving community members no respite during sleep. Air-conditioning (AC) adoption rates in the region are some of the lowest in the United States. Nationwide about 91 percent of homes have AC, but only 78 percent of Portland homes and 44 percent of Seattle homes do (U.S. Census Bureau 2020).

An estimated 1,200 heat-related deaths are estimated to have occurred during the heat wave, with many more hospitalizations for heat-related illnesses occurring across the region (British Columbia 2021; Popovich and Choi-Schagrin 2021). The young, elderly, pregnant women, outdoor workers, those with lower incomes, and people experiencing homelessness were particularly at risk during the heat wave.

In addition to the human impact, the heat wave buckled sidewalks, roads, and highways across the region while also melting overhead transit lines in Portland. Some schools and businesses in the region closed because they lacked indoor cooling. The heat wave also strained the energy grid, leading to rolling blackouts in some locations. Over a billion marine animals died along the coast when the water in their shallow tidal pool habitats overheated (Einhorn 2021). The extreme heat also further stressed drought-stricken forests, resulting in numerous wildfires across the region. A wildfire swept through and destroyed almost all of Lytton just days after the village saw its record-breaking temperatures. The loss of vegetation from these extreme heat-driven wildfires increased the severity of record-breaking floods in British Columbia that occurred in early November, temporarily cutting Vancouver off from the rest of Canada.

Figure 1.2. The Oregon Convention Center in Portland was repurposed as an emergency cooling center during the Pacific Northwest heat wave (Multnomah County)

A preliminary analysis concluded that the Pacific Northwest heat wave was a 1-in-1,000-year event in today's climate. Before climate change, this would have been considered a 1-in-150,000-year event, meaning it would have been almost statistically impossible without the influence of greenhouse gas emissions (Philip et al. 2021). As global warming continues, extreme events like this heat wave will be more likely to occur—even in historically cooler regions like the Pacific Northwest.

described in the sidebar on p. 11. In addition to mortalities, extreme heat events lead to increased hospitalizations and impacts to urban ecology and built infrastructure.

Chronic heat affects the long-term social, environmental, and economic viability of communities. It mirrors other socioeconomic disparities more closely than extreme heat events. Inequitable distribution of heat exposure across a community, lack of quality housing, insufficient income, and unsafe work or transportation options often exacerbate the chronic risk of heat for the most marginalized communities (Mitchell and Chakraborty 2018; Wilson 2020). Policies that address socioeconomic and public health disparities are needed to reduce chronic heat risks (Putnam et al. 2018).

Planners are already concerned about heat risks. In a 2018 American Planning Association (APA) survey of U.S. planners, 70 percent expressed concern about extreme heat risk in the communities in which they work, ranking heat fourth out of 15 possible natural hazards in terms of concern (APA and NDMC 2018). A 2020 survey found that 84 percent of planners from communities across the United States believed that their community had been impacted by extreme heat within the last five years (Meerow and Keith 2021). Despite growing impacts and concern, however, an assessment of 3,500 climate adaptation resources found that only four percent provided specific guidance for heat (Nordgren, Stults, and Meerow 2016).

While urban resilience is an increasingly popular planning concept, heat resilience planning has received less attention than other hazards such as flooding or wildfire. The purpose of this PAS Report is to provide urban planners and allied professionals with a holistic guide to increase urban heat resilience equitably in the communities they serve. This introductory chapter overviews the impacts to communities of urban heat, explains why planners are well positioned to address this challenge, and provides a roadmap to the contents of this report.

IMPACTS OF URBAN HEAT

While extreme heat risk is commonly associated with public health risks, impacts have been documented across urban systems, including social, ecological, economic, and infrastructure systems. Many of these impacts are interconnected and urban heat often compounds other climate risks and urban challenges. As noted above, the majority of planners in cities across the United States reported that their communities had been affected in some way by extreme heat, and most were concerned about heat's environmental and health impacts (Meerow and Keith 2021).

Social Impacts

Urban heat has a number of social impacts that often disproportionally affect marginalized and disenfranchised communities due to the inequitable distribution of heat severity in urban areas. These social impacts include public health and quality of life concerns.

Public Health. Public health is the most commonly referred to impact of extreme heat, and for good reason. Extreme heat is the deadliest U.S. weather-related risk (Hondula et al. 2015) and accounts for a larger portion of the public health burden than most other natural disasters combined (Berko et al. 2014).

When the human body becomes hotter than it can regulate, heat-related illnesses occur, including heat rash, heat cramps, heat exhaustion, and heat stroke. Strenuous activities in dangerous temperatures and humidity can quickly cause heat-related illness, but exposure to high temperatures over a long period of time and during the night also has a detrimental impact on human health. Extreme heat exacerbates preexisting conditions such as asthma, heart disease, and diabetes; increases the risk for pre-term births (Barreca and Schaller 2020); increases hospital admissions for mental health-related issues by as much as 7.3 percent (Hansen et al. 2008); and elevates the risk of suicide (Thompson et al. 2018). This places some

Figure 1.3. Cooled tents at the University of Arizona's outdoor COVID-19 vaccination site were needed to help protect volunteers, staff, and clients from heat exposure in 2021 (Nicole Iroz-Elardo)

KEY TERMINOLOGY

A short list of key heat-related terms is provided below to introduce readers to the most frequently used terms throughout this PAS Report. It should be noted that term usage can vary among different agencies and stakeholders, and there is no single resource that defines heat-related terms for planning practitioners.

Climate change: The change of climate due directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods (United Nations 1992).

Early warning systems: The U.S. NOAA National Weather Service issues outlooks such as heat advisories (within 12 hours), excessive heat warnings (12 to 24 hours before), and excessive heat watches (24 to 72 hours) when dangerous heat becomes likely or imminent (U.S. NOAA 2021).

Extreme heat: Temperatures that are much hotter and/or more humid than average for a particular time and place (U.S. CDC 2017).

Extreme heat event: A series of days that are hotter and/or more humid than average for a particular time and place. Also referred to as heat waves (U.S. CDC 2017).

Heat equity: The development of practices and policies to mitigate and manage heat with a focus on reducing the inequitable distribution of risk across different groups within the same community (U.S. EPA n.d.).

Heat management: Preparation and response strategies for extreme heat events, often within the domain of emergency management or public health (Keith, Meerow, and Wagner 2020).

Heat mitigation: Design and planning strategies to reduce the contribution of the built environment to urban heat (Keith, Meerow, and Wagner 2020).

Thermal comfort: How heat is perceived and experienced by the human body. Thermal comfort is influenced by ambient air temperature, air speed, humidity, radiant temperature, clothing insulation, and the body's metabolic rate.

Urban heat: Hotter conditions in urban areas caused by a combination of the climate, characteristics of the built environment, and waste heat (U.S. EPA 2021b).

Urban heat island (UHI): The temperature differences between an urban area, which is typically hotter due to the built environment and waste heat, and surrounding rural and natural areas. Temperatures can also vary substantially within the same community (U.S. EPA 2008a).

Urban heat resilience: Proactively managing and mitigating urban heat across the many systems and sectors it affects.

communities at higher risk; diabetes is twice as prevalent within federally recognized tribes than the general population (USGCRP 2018).

While acute extreme heat events are a clear concern to public health, chronic heat also poses serious public health risks to those with poor quality housing or preexisting health conditions, those working outdoors or in spaces without adequate cooling, and those unable to afford indoor cooling at home. Extreme heat compounds other public health risks. One example of this is the COVID-19 pandemic (Phillips et al. 2020), during which the use of heat management strategies such as cooling centers was disrupted and early mass vaccination efforts required consideration of personal heat exposure (Figure 1.3, p. 12) (Keith, Iroz-Elardo, et al. 2021).

Education. While outdoor educational activities can be temporarily halted during extreme heat events, learning outcomes are also disrupted by extreme heat. A study of educational achievement data in 12,000 U.S. school districts and 58 counties found that the rate of learning decreased with the increase in hot school days (Park, Behrer, and Goodman 2021).

Quality of life. The quality of life of community members is a central concern to the planning profession and can also be negatively impacted by extreme heat. Increasing temperatures can require modifications to outdoor activities, causing people to shift activities such as commuting by bicycle, taking children to a park, or walking a dog to early mornings or late evenings when temperatures are cooler. While these changes can be helpful adaptations to heat, they can also serve to limit or discourage outdoor activities altogether.

Environmental Impacts

Urban heat also has a number of environmental impacts, particularly on landscapes and urban ecology.

Landscapes. Urban landscapes require substantial investment with their planning, installation, and maintenance over their lifetimes. Increasing temperatures can limit the richness and diversity of urban vegetation (Brans et al. 2018) as well as negatively impact the growth of urban trees (Nitschke et al. 2017). Required or recommended plant lists by local governments are often based on which plants historically have done well in an area in the past (including native species), but increasing temperatures may make many of these species ill-suited if they are less heat tolerant.

Urban ecology. The impacts of the UHI effect on urban ecology and the ecological systems within urbanized areas have been well documented. When urban areas are substantially warmer than pre-existing surrounding natural landscapes, a different set of plants and animals may thrive. These can range from monk parrots becoming established in Brooklyn, New York (Rodríguez-Pastor et al. 2012), to tropical and subtropical mosquito species and their associated diseases gaining a foothold in colder climates (Franklinos et al. 2019).

Economic Impacts

The substantial and increasing economic impacts due to extreme heat can affect workforce productivity, retail sales, tourism, and the competitiveness of regions.

Workforce. Economic productivity is impacted by extreme heat events, with an estimated 153 billion labor-hours lost globally in 2017 (Watts et al. 2018). By 2050, global economic productivity is projected to decline by 20 percent during hot months (Dunne, Stouffer, and John 2013). Extreme heat particularly affects the productivity, health, and safety of outdoor workers, such as landscapers, agricultural workers, laborers, and construction workers. Outdoor work is disproportionately done by immigrants and minorities, highlighting the economic disparities of heat risk (Dahl and Licker 2021).

Tourism. Extreme heat events can depress attraction visits in the short term, but long-term temperature increases may also change visitor preferences and impact local economies. Some of these visitor preferences may be for shorter visits during the remaining cooler season, but there may be thresholds where visitors select new locations entirely. One study found that increasing temperatures could decrease the overwinter stays by “snowbirds” in Coachella Valley, California, by up to 36 percent by 2100 (Yañez, Hopkins, and Porter 2020).

Regional competitiveness. Much as coastal cities are adapting to sea level rise and ensuring that their cities will remain economically competitive (Hinkel et al. 2018), a similar dynamic may begin to play out in hot cities that experience increasing frequency and duration of extreme heat events. While dramatic media headlines that predict the demise of cities are overblown, increasing climate risks do have real-world economic consequences for cities when workers or companies are relocating.

Infrastructure Impacts

Extreme heat has impacts across built infrastructure systems. These include water, energy, and transportation systems—all central to the functioning of communities.

Water. Water use increases with rising temperatures, particularly as landscapes need more watering during hot temperatures; many heat mitigation strategies, however, include increased vegetation. A low-temperature increase of only 1°F (0.6°C) leads to an increase of single-family water use by an estimated 290 gallons per month (Guhathakurta and Gober 2010). Water treatment plants can also be strained by extreme heat (Zuo et al. 2015). An Australian study found that water conservation efforts might negate heat reduction efforts (Hatvani et al. 2018), making this an important focus area to avoid potential conflicts.

Energy. Energy use and the energy grid system are also closely connected with increasing temperatures. Between three and eight percent of U.S. energy demand has been attributed to increased air conditioning due to the UHI effect (Grimm et al. 2008). Extreme heat also strains the reliability and operation of energy infrastructure (Ward 2013), with the risk for an energy grid blackout during an extreme heat event being a major concern (Stone, Mallen, Rajput, Gronlund, et al. 2021). Increased energy use due to extreme heat results in more greenhouse gas emissions, which accelerates climate change and increases global temperatures. Waste heat from energy production, automobile use, and air conditioning cause a similar feedback loop, increasing urban temperatures.

Transportation. Extreme heat also affects transportation infrastructure. Alternative transportation modes are particularly at risk if they are not designed with heat in mind. This includes pedestrian and bicycle-friendly corridors but also transit use and transit station design (Dzyuban et al. 2021). Air travel will also be affected, as airplanes are unable to take off from runways above a certain temperature. These airplane groundings are projected to increase by 50 to 200 percent at several major airports in the United States by 2070 (Coffel and Horton 2015).

Sustainability and Resilience Impacts

Increasing temperatures can make it more difficult to achieve sustainability and resilience planning goals. Planning strategies to address urban heat must keep the complex interactions of heat with urban systems and its long-term impacts in mind to avoid *maladaptation*—adaption actions that have unintended negative consequences.

As temperatures rise, unmitigated heat in urban areas could make walking and bicycling less attractive transportation alternatives, with both public health and greenhouse gas emissions consequences. Mixed-use and walkable urban spaces could also become less attractive unless properly shaded and designed with heat mitigation in mind, potentially contributing to continued lower-density and automobile-dependent urban growth at the edges of cities. Integrating urban heat resilience into planning processes and built environment design will help avoid these longer-term impacts (Figure 1.4).

Figure 1.4. The Sonoran Desert Laboratory Garden was designed for use by students and faculty, even during hot summer months, at the University of Arizona's College of Architecture, Planning, and Landscape Architecture (University of Arizona, CAPLA)

PLANNING FOR URBAN HEAT RESILIENCE

At its core, urban resilience is about a community's capacity to cope with rapid shocks and chronic stresses, and heat can manifest as both. Some communities, such as those in the U.S. South and Southwest, have high temperatures for many months of the year and certain areas are consistently hotter than others due to various factors. Other communities increasingly experience short-term heat waves and associated infrastructure failures.

Urban heat resilience means proactively managing and mitigating heat across the many systems and sectors it affects. This PAS Report specifically defines urban heat resilience as follows:

> Urban heat resilience is the ability of an urban system—and all its constituent social-ecological-technical systems across temporal and spatial scales—to maintain or rapidly return to desired functions and improve quality of life in the face of chronic and acute heat risks, and to quickly transform systems that limit current or future capacity to adapt to extreme heat. (adapted from Meerow, Newell, and Stults 2016)

This definition suggests that resilience is not so much about avoiding impacts, "bouncing back," or recovering, but rather "bouncing forward" and improving in the face of challenges (Island Press and Kresge Foundation 2015). Figure 1.5 (p. 16) presents the components of urban heat resilience, including considerations for heat contributors, heat impacts, and heat resilience strategies.

Enhancing urban heat resilience requires holistic strategies that recognize the connections between different urban systems and across scales. Planning strategies include efforts to mitigate heat in urban areas (e.g., through vegetation or design of the built environment) and manage heat risks (e.g., through emergency response or social services). As a result, heat risks need to be addressed in an integrated way across community planning efforts, from comprehensive to hazard mitigation to climate action plans.

For heat mitigation, practitioners in urban planning, landscape architecture, architecture, hazard mitigation

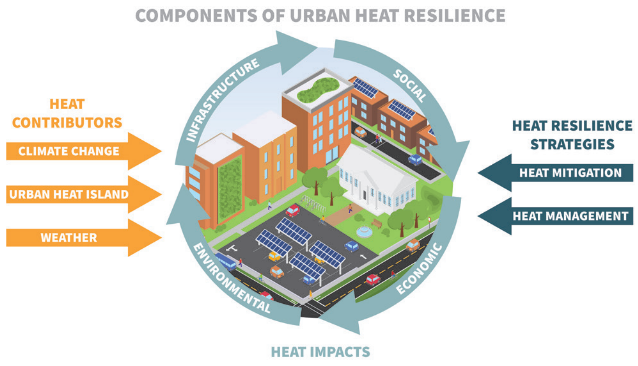


Figure 1.5. The components of urban heat resilience include heat contributors, heat impacts, and heat resilience strategies (Ladd Keith and Sara Meerow)

planning, and real estate development are critical. For heat management, practitioners in public health, emergency management, and the energy sector are key. Geospatial specialists and climatologists can also help guide decision-making for both heat mitigation and management. While many of the strategies to address urban heat risk occur at the local government level, state and federal resources are significant, particularly for smaller communities with less capacity to individually assess heat risk and develop strategies. Universities play a role in conducting urban heat research and evaluating the effectiveness of different strategies. Nongovernmental organizations and nonprofits are also key in informing constituencies about their risks and engaging communities in addressing urban heat risk.

Urban heat resilience is a rapidly developing area of practice, and the urban planning profession is well poised to take a leading role (Keith, Meerow, and Wagner 2020). Urban planning is the only profession at the intersection of land use, transportation, and urban design, with expertise in working across disciplines. Planning has historically been charged with protecting a community's health, safety, and quality of life. The planning profession is also committed to addressing both the causes and impacts of climate change; according to the APA, planners need to take the lead in helping to mitigate the impacts of climate change and ensuring our communities adapt to a changing climate (APA 2020). Finally, planners have a special responsibility to redress heat inequities within communities, which were caused in part by past planning decisions. Heat equity should be included within the broader environmental justice agenda.

Planners already have tools to shape land use and the built environment, which crucially shape current inequities in heat exposure and can help redress those inequities going forward (Wilson 2020). And planners have a key role in facilitating community engagement, which is critical to ensure that heat mitigation and management strategies draw from local knowledge and are appropriate when applied.

ABOUT THIS REPORT

This PAS Report is written for practitioners with different levels of knowledge of and experience with urban heat. While planners are a key audience, the report holistically lays out urban heat resilience and highlights opportunities for collaboration with other key professions and disciplines.

For practitioners less familiar with urban heat, the first part of the report (Chapters 2–3) provides an in-depth overview of the causes and contributors to urban heat and equity implications. The second part of the report (Chapters 4–8) lays out an urban heat resilience framework and offers a variety of heat mitigation and management strategies for practitioners of all familiarity levels with urban heat.

Chapter 2, Understanding the Complexities of Urban Heat, provides a practical guide for understanding urban heat. This includes the science behind contributing factors such as the UHI effect, climate change, and weather variability. It also covers the importance of local context and how geography, climate, and the built environment affect urban heat risk. Finally, it introduces several information sources critical to understanding urban heat risk and their appropriate uses.

Chapter 3, Equity and Urban Heat, builds on the previous chapter by exploring how past urban planning practices have contributed to current inequities in heat severity and heat response in communities. It lays out the discriminatory legacy of practices such as redlining and the connections between urban heat and other equity concerns. Finally, it offers areas in which the planning profession can advance equitable urban heat resilience.

Chapter 4, Urban Heat Resilience Planning Framework, introduces the Plan Integration for Resilience Scorecard for Heat (PIRSH) and methods for assessing how a community's current planning efforts are likely to impact urban heat resilience. It also offers suggestions for determining urban heat goals and metrics for success, opportunities for collaboration, and resource considerations.

Chapter 5, Urban Heat Mitigation Strategies, provides an overview of urban heat mitigation strategies for the built environment. These strategies include land use and urban design, urban greening, and energy efficiency improvements. Several case studies of innovative heat mitigation strategies are also presented from communities across the United States.

Chapter 6, Urban Heat Management Strategies, provides an overview of emergency response and preparation strategies for extreme heat events. It also describes the role of the planning profession in these strategies and how planners can better coordinate with other professions that typically lead these areas. Several examples of emergency response and preparation strategies are highlighted from U.S. communities.

Chapter 7, Planning Tools for Urban Heat Resilience, provides practical guidance on how the urban heat strategies discussed in the previous two chapters can be integrated into existing urban planning activities, processes, plans, and regulatory tools. These include community engagement, long-range planning, development regulations and review, and public financing options.

Chapter 8, Advancing Urban Heat Resilience, provides a summary of the report, discusses how to address uncertainties and challenges, and identifies where future advances in practice and research are needed.

A separate report by this report's authors and several other collaborators, which is related to this PAS Report, lays out the Plan Integration for Resilience Scorecard for Heat (PIRSH) in more detail with a workbook to help get communities started.

CHAPTER 2

UNDERSTANDING THE COMPLEXITIES OF URBAN HEAT

Urban heat has been called an “invisible” climate risk despite its increasing impacts across social, environmental, economic, and infrastructure systems. The impacts of even the most extreme heat events are not as visible as the dramatic news images of wildfires, hurricanes, floods, or sea level rise.

Another challenge is that urban heat risk is a complex climate risk, with many interconnected contributing factors and even more ways to approach understanding it. While the science and practice of urban heat are rapidly advancing, enough is known today to better plan communities to mitigate and manage heat. If planners have a basic understanding of the complexities of urban heat, they will be better able to target solutions to the particular heat conditions in their communities and ensure those heat considerations are coordinated across plans.

This chapter provides a practical guide for understanding the complexities of urban heat, including the contributing factors of climate change and the urban heat island (UHI) effect. It explains the concept of thermal comfort, or how humans experience heat, and it describes key organizations and disciplines critical to governing urban heat at the local, state, and federal levels. Finally, the chapter presents a variety of urban heat information sources, with details on where planners can access these resources and how they can use them.

CLIMATE CHANGE

Climate change due to human-caused greenhouse gas emissions is increasing global average temperatures (IPCC 2021). Global average annual temperatures have already increased 2°F (1.1°C) since 1880, and the ten warmest years have all occurred since 2005 (U.S. NOAA National Centers for Environmental Information 2021).

For the contiguous United States, annual average temperatures have already increased by 1.8˚F (1.0°C) since 1900, with an additional 2.5°F (1.4°C) projected in the next few decades due to the greenhouse gases already emitted (USGCRP 2018). Depending on the world’s future emissions reductions, the United States will experience an average temperature increase between 3°F (1.7°C) and 12°F (6.7°C) by 2100 (USGCRP 2018).

Figure 2.1 shows projected changes for annual average temperature in North America by both the mid- and late-21st centuries. The lower scenario (RCP4.5) is if carbon emissions are drastically and immediately cut, and the higher scenario (RCP8.5) is the worst-case emissions increase.

Urban planners must plan for urban heat and continued increases in annual average temperatures now, as some level of future warming will occur regardless of emissions mitigation efforts. Planners must also strengthen local emissions

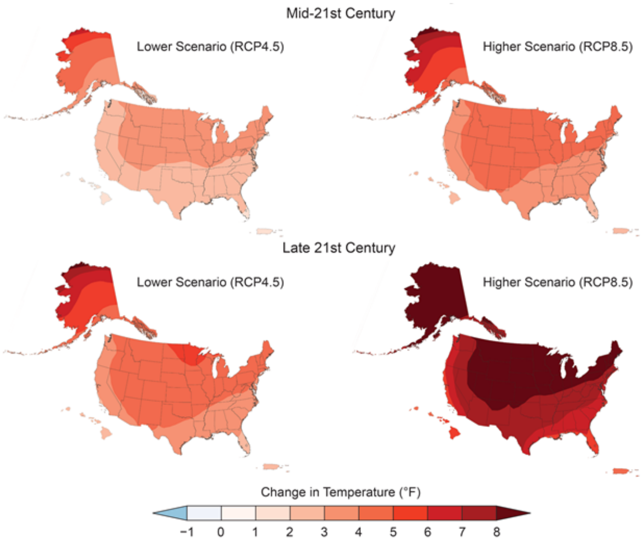


Figure 2.1. Projected best- and worst-case scenarios for annual average temperature changes in North America by both mid- and late-21st century (USGCRP)

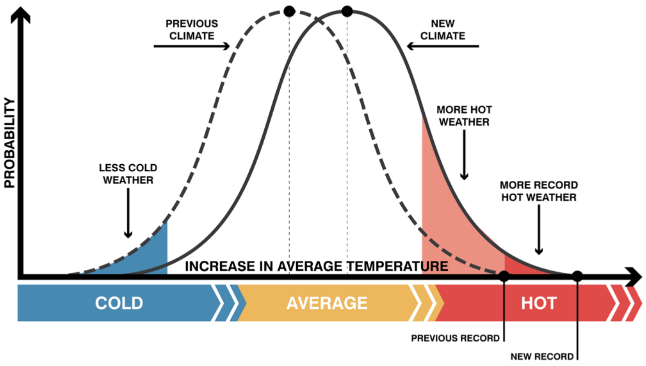


Figure 2.2. Even a small increase in average temperature can greatly increase the likelihood of extreme heat events and record hot weather (Ladd Keith and Sara Meerow)

mitigation efforts to ensure that worst-case temperature increases are avoided. Almost half of U.S. planners surveyed in 2020 indicated that they were very concerned about climate change as a contributor to extreme heat, more so than the UHI effect (Meerow and Keith 2021).

While there will continue to be natural climate variability, or the cooler and hotter periods of weather that occur naturally in the global climate system, climate change is pushing that variability to hotter averages and extremes. Even with small increases in average temperature due to climate change, cooler periods will be closer to historically average temperature periods, and the likelihood of hotter weather and more record-breaking hot weather will increase (Figure 2.2).

These changes will push many communities into new climate thresholds with respect to heat. Chronic heat risk will increase as average temperatures increase and temperatures stay hotter for longer periods of time. Acute heat risk will also increase, continuing the past half-century's trends of greater frequency, duration, season length, and intensity of extreme heat events (Figure 2.3) (U.S. EPA 2021a). The frequency of these extreme high temperatures and extreme heat events are projected to increase even more than average annual temperatures (USGCRP 2018). Extreme heat event days are projected to increase between four to 34 days per season for each 1.8°F (1°C) of increased global average warming (Perkins-Kirkpatrick and Lewis 2020).

The local context of climate is critical, as historical and projected temperatures are not uniform across the country. In some regions, such as the Southwest, summer temperatures above 90°F (32.2°C) may already be normal, whereas in other regions, such as the Northeast, summer temperatures that high were historically rare, but are now an increasingly common occurrence. Heat within regions often differs too; for instance, the average summer temperature in Los Angeles is just above 80°F (26.7°C), while the average summer temperature 100 miles away in Palm Springs, California, is 99°F (37.2°C).

Historic climate conditions influence a community's current heat adaptiveness, or the adjustments and behavior changes already made for heat. An example of heat adaptiveness is the adoption of air conditioning. Historically hotter areas, such as the Southwest, Southern Great Plains, and South, have high air conditioning adoption rates, whereas cooler areas, such as the Northwest, Northern Great Plains, Midwest, and Northeast, have lower adoption rates. This history shapes how communities in different areas will experience, prepare, and respond to both chronic and acute heat risk. Regardless of current heat adaptiveness, all communities in the United States face increasing heat risk.

URBAN HEAT ISLAND EFFECT

The way urban areas have been planned and built, and how they are operated, increases their temperature through the UHI effect (Oke 1973). As described in Chapter 1, the UHI effect results in urbanized areas being hotter than their surrounding rural or natural areas (Oke 1973). While the UHI effect was first documented in the 19th century in London (Howard 1818), the availability and improvement of satellite remote sensing imagery have brought UHI mapping and modeling to the forefront of research in recent decades.

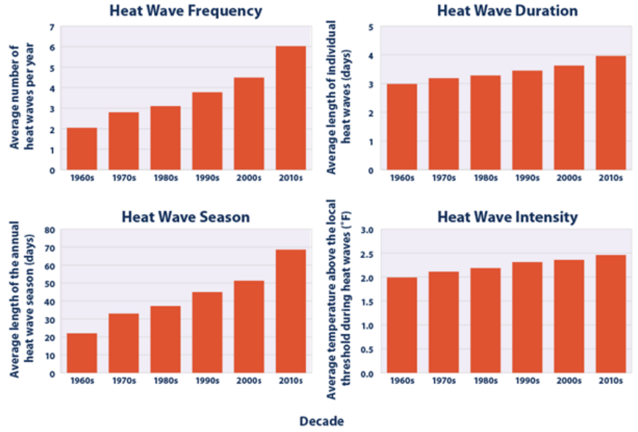


Figure 2.3. Increases in heat wave frequency, duration, season, and intensity from 1961 to 2019 for 50 large metropolitan areas in the United States (U.S. EPA)

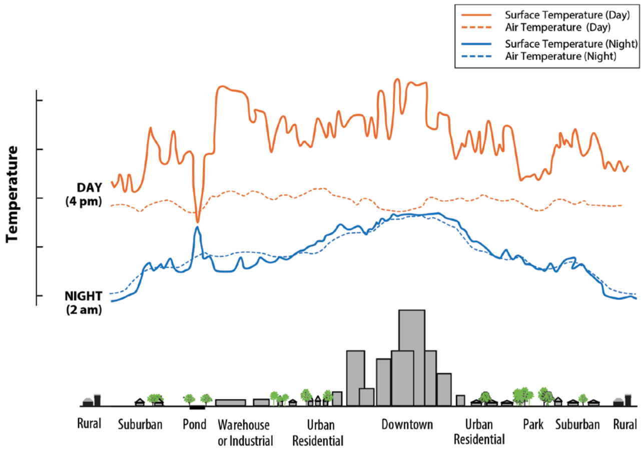


Figure 2.4. The UHI effect across the built and natural environment, with surface temperature differences shown during both day and night (U.S. EPA)

Due to the UHI effect (Figure 2.4), daytime temperatures in urban areas can be 1–7°F (0.56–3.9°C) higher than surrounding areas, and the nighttime temperature difference can be 2–5°F (1.1–2.8°C) higher (Hibbard et al. 2017). The increased nighttime temperatures can be a particular public health concern, as a reduction in nighttime cooling can lead to higher heat-related illnesses and deaths.

The heat severity caused by the UHI effect also varies across and within urbanized areas, with some areas being hotter than others due to their characteristics. For example, differences in vegetation, such as tree canopy, influence the severity of the UHI effect (Figure 2.5, p. 22). Several other characteristics that influence the UHI effect include the following:

- **Loss of rural and natural landscapes.** A major contributor to the UHI effect is the development of rural or natural landscapes, which are often more vegetated and have less heat-trapping materials than urban areas. Natural ground surfaces, vegetation, trees, and bodies of water are all typically cooler than urbanized areas. As these natural areas are developed, the UHI effect for the urbanized area will likely increase. Agricultural landscapes can be similarly cooler than urbanized areas, although this may be dependent on the seasonality of crops, as unused fields may increase the UHI effect. While urban areas in arid or semi-arid environments may have a UHI effect, some urbanized areas can be cooler than the surrounding natural areas due to water usage that increases vegetation cover beyond what would be present naturally. The conservation of natural and rural landscapes around urbanized areas can help preserve their cooling benefits.
- **Urban form.** The urban form, or the physical characteristics of the built environment itself, also influences the UHI effect. This includes considerations of building density, height, and arrangement, which can, in turn, affect factors such as shading and ventilation. Density itself does not cause the UHI effect, because the UHI effect is also impacted by regional development patterns. Large sprawling developments with many road surfaces and large parking lots can increase the UHI effect more than well-designed densely developed areas.
- **Materials used.** Materials such as dark pavement and roofing can absorb more heat throughout the day and then slowly release it at night. Both the type of material used and its reflectivity affect how much heat is absorbed and how quickly or slowly it is released. This is in contrast to vegetation and natural surfaces, which typically absorb less heat and cool off more quickly. Strategic shifts to reduce the overall extent of pavement and hard surfaces, increase vegetation, and use cooler paving surfaces, walls, and roofs can help mitigate the UHI effect.
- **Waste heat emissions.** Waste heat emissions from the operation of vehicles, building systems such as air conditioning, and industrial facilities all contribute to the UHI effect. Paradoxically, during extreme heat events, many of these waste heat-emitting sources are used more heavily, further exacerbating heat risk. Waste heat emissions do represent an opportunity area, as reductions in vehicle use and more efficient building systems can simultaneously lead to both the mitigation of the UHI effect and a reduction in greenhouse gas emissions.
- **Geography.** Local geographic features such as hills or mountains and bodies of water influence the characteristics of the UHI effect. In urban areas that cover a large region, there is often a sizable difference in the UHI effect based on elevation changes and the presence of topographic features that reduce or increase naturally occurring wind patterns.
- **Weather.** Weather conditions also influence the UHI effect on a day-to-day basis. In general, higher winds and cloud cover will limit the UHI effect, while calm wind and sunny conditions can result in a more severe UHI effect.

As denser, more central urban areas often have a higher UHI effect, this can be misinterpreted to mean that lower-

Figure 2.5. Dramatic differences in tree canopy only a few streets apart in San Jose, California, influence the UHI effect (C.J. Gabbe)

density development is, therefore, the remedy to urban heat. In reality, research has documented that the total urban area contributes to the UHI effect, and that sprawling low-density metropolitan areas often have a higher UHI effect than compact and denser metropolitan areas (Stone 2012; Stone and Rodgers 2001). This is because sprawling development patterns result in more vegetation loss, impervious surface, and waste heat generation per capita compared to compact development. Well-designed compact development can achieve density goals while also contributing less to the UHI effect than comparable sprawling development (Turner and Galletti 2015).

When discussing urban heat, it is important to consider scale. The relationship between the regional UHI effect and the actual heat experienced within microclimates is complex. A microclimate is the unique climate conditions within a small area, such as a single site or neighborhood. The effect of a particular site design on the microclimate can be different from how it affects the regional UHI effect. For example, a "cool roof" (a roof made of materials or covered in coatings that are highly reflective) on a multistory apartment building may reduce heat absorption, energy use, and waste heat emissions from the building, thereby reducing the regional UHI effect, but it might not create a cooler environment for pedestrians on the adjacent sidewalk. Similarly, the addition of a shade tree at a bus stop helps create a respite from the heat for transit users but does little by itself to reduce the UHI effect created by the adjacent large roadway. Both the larger UHI effect and microclimates must be considered when planning for heat mitigation at multiple scales.

THERMAL COMFORT

To further complicate matters, air temperature alone does not determine how humans experience heat, also known as thermal comfort. Humidity is another important factor, as higher humidity levels make the body less able to respond to high temperatures. This is why a "dry heat" feels better than a "wet heat" at the same temperature.

Thermal comfort is also determined by mean radiant temperature and wind speed. Mean radiant temperature primarily comes from thermal radiation from the sun, but it can also come from other surrounding objects that radiate heat, such as machinery or pavement. Shade is highly effective at blocking thermal radiation from the sun. Mean radiant temperature is why it might feel significantly hotter in an unshaded parking lot than a neighboring covered patio.

Other considerations for human thermal comfort are what clothing a person is wearing and their age, fitness, and overall health. Each individual also has a level of acclimatization, or how accustomed they are to various climate conditions. Someone who spends the majority of their time in air-conditioned environments indoors can take between one and two weeks to become acclimated to working in hotter outdoor conditions. This can make infrequent time spent outdoors during hot weather particularly dangerous if caution is not taken. Acclimatization, or lack thereof, also varies by region.

It is important to consider an individual's thermal comfort throughout their day and night, as it can change as they sleep, travel to work, work in a building or outdoors, and run errands. Each activity changes their thermal comfort as they move through different locations with different climate conditions, and those conditions typically change over the course of the day.

Different heat stress indexes are used to approximate human thermal comfort, and they are more accurate than air temperature alone, but each index has advantages and disadvantages based on how it is calculated. Two commonly used indices discussed below include the National Weather Service's Heat Index and the wet bulb globe temperature (WBGT). There are many additional heat stress indices, such as the Universal Thermal Climate Index (UTCI) and Physiological Equivalent Temperature (PET).

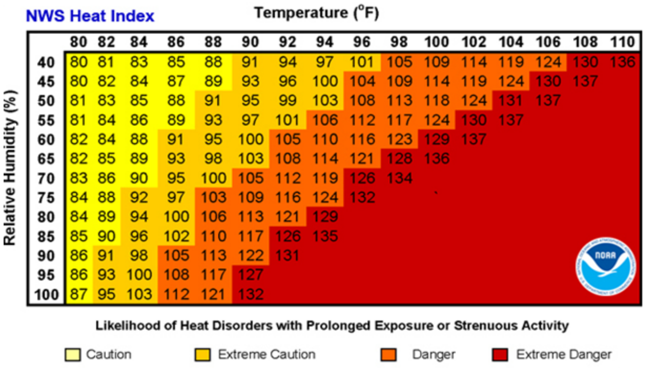
Heat Index

In the United States, the National Weather Service (NWS) uses the Heat Index as a standardized way to alert the public about heat risk (Figure 2.6).

The Heat Index uses both air temperature and relative humidity to calculate the likelihood of heat illness with prolonged exposure or activity. Higher relative humidity levels greatly increase the Heat Index. For example, 90°F (32.2°C) with 40 percent relative humidity is recommended for "Extreme Caution," while 90°F (32.2°C) with 95 percent relative humidity is recommended for "Extreme Danger."

While the Heat Index is a more accurate representation of heat risk than air temperature due to its inclusion humidity, it cannot take into account how a person experiences heat due to local microclimate differences.

Wet Bulb Globe Temperature (WBGT)



NWS Heat Index

Temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

☐ Caution ☐ Extreme Caution ☐ Danger ☐ Extreme Danger

Figure 2.6. The Heat Index displays the likelihood of heat illness based on both air temperature and humidity (U.S. NOAA)

Figure 2.7. A portable device collects wet bulb globe temperature while Tucson Sun Link Streetcar riders find respite from the heat in the shade (Ida Sami, University of Arizona)

The wet bulb globe temperature (WBGT) is a more comprehensive way to approximate human thermal comfort through the use of portable devices that record ambient air temperature, humidity, wind speed, and radiant heat (Figure 2.7). WBGT is often used in athletic and occupational settings, such as by the military, to help safely manage outdoor activities.

WBGT is a more accurate on-site representation of personal heat exposure than the Heat Index, which only takes humidity and air temperature into account. WBGT can also be used to better understand human thermal comfort at the site level by urban planners and designers, information which can then be used to improve microclimate factors like shade and ventilation.

GOVERNING URBAN HEAT

Urban heat is increasingly recognized as a risk, and in 2021, Miami-Dade County, Florida, became the first local government in the United States to appoint a Chief Heat Officer (Miami-Dade County 2021). This was soon followed by the announcements of similar positions in Phoenix (Phoenix 2021b); Athens, Greece (Horowitz 2021); Freetown, Sierra Leone (Harrisberg 2021); and Los Angeles (Bush and Lozano 2021). While the specific functions of these staff are still being determined, they are generally tasked with coordinating efforts across city departments to address heat, tracking heat-related metrics, raising awareness, and developing policies around heat.

The urban governance landscape is evolving quickly, but urban heat has historically lacked a "problem owner" (Keith, Meerow, et al. 2021). Local, state, and federal governance for urban heat is relatively new and lacking compared to other climate risks such as urban flooding, wildfire, and drought. As a complex climate risk with social, environmental, economic, and infrastructure system impacts, heat also requires coordination across disciplines such as urban planning, the design professions, public health, emergency management, and climate services.

Local Government

Urban heat can be addressed across different levels of local government and siloed disciplines, making improved coordination a key consideration for urban heat planning. All local government levels are critical to involve, including incorporated towns and cities, counties or parishes, and regional governments if they are present. This was confirmed in a 2020 survey of planners, who largely agreed that all levels of government had a role to play in heat planning (Meerow and Keith 2021).

Examples of departments that should be considered include long-range planning, development and building review, community development, parks and recreation, transportation, emergency management and hazard mitigation planning, and public health. GIS staff can play an essential role in helping coordinate heat-related information and aligning it with existing information used for decision-making. Sustainability or climate resilience staff, when they are available, can also help better coordinate siloed efforts between departments. Local libraries, community and recreation centers, and public schools, which can double as cooling centers and help with heat education and awareness, should also be considered vital partners.

State Government

States are less commonly involved in heat planning efforts but still can provide important resources and coordination assistance. State health departments often interface closely with county health departments and can coordinate heat-related public health efforts. For states that have climate-related planning mandates and resources, urban heat should be one of the climate risks addressed. Many states offer some level of assistance to help support local emergency management or hazard mitigation planning activities. States' occupational health and safety offices are critical for protecting outdoor workers from heat illnesses and deaths. States should also ensure resilient energy grid operations, as well as affordable and reliable energy service. Each U.S. state and Puerto Rico has a state climatologist, a resource for locally relevant information on heat risks and planning efforts.

Federal Government

As with local government, different federal government agencies deal with different aspects of heat. Key agencies include the National Oceanic and Atmospheric Administration (NOAA) for weather and climate, the Centers for Disease Control and Prevention (CDC) for public health, the U.S. Environmental Protection Agency (EPA) for urban heat reduction information, and the Federal Emergency Management Agency (FEMA) for emergency management and hazard mitigation planning.

The cross-cutting National Integrated Heat Health Information System (NIHHIS) is an effort developed by NOAA and the CDC to coordinate and improve several agency initiatives related to heat and public health. The sidebar on p. 25 provides further information on the support offered by these agencies and their collaborations.

Other federal agencies also intersect with urban heat considerations to provide information on additional topics:

- U.S. Department of Agriculture, for agricultural worker heat safety and preservation of agricultural lands around urban areas
- U.S. Department of Energy, for building energy efficiency and national grid resilience
- U.S. Department of Health and Human Services, which administers the Low Income Home Energy Assistance Program (LIHEAP)
- U.S. Department of Housing and Urban Development, for thermally safe public housing
- U.S. Department of Labor, for worker heat safety
- U.S. Department of Transportation, for thermally safe transportation options

Planners can reach out to these agencies and others to gather additional information on the heat issues that impact their specific communities.

Nongovernmental Organizations

Nongovernmental organizations (NGOs) also play a role in urban heat governance. Organizations such as the Red Cross provide critical emergency management support, while others like The Trust for Public Land and The Nature Conservancy provide resources and advocacy for urban greening initiatives that can help to mitigate heat. Other examples include the Global Cool Cities Alliance, which aims to advance heat

FEDERAL URBAN HEAT RESOURCES

Several federal agencies provide critical information, resources, and assistance to communities for urban heat. There are also several cross-cutting federal programs critical for heat-related information. For communities seeking to either begin or advance urban heat resilience efforts, these agencies and programs provide a wealth of information, often tailored to local and regional needs.

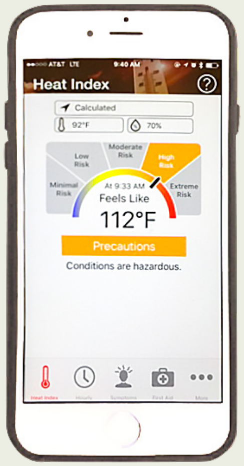
National Oceanic and Atmospheric Administration (NOAA). NOAA has several programs relevant to urban heat planning efforts. The National Weather Service (NWS) has local offices across the United States specializing in understanding the weather patterns in communities they serve and issuing heat warnings and watches. The Regional Integrated Sciences and Assessments (RISA) program is tasked to support the nation's capacity to prepare for and adapt to climate variability and change. RISA programs are hosted by university collaborations and specialize in connecting climate science to decision-maker needs, such as planning for urban heat.

Centers for Disease Control and Prevention (CDC). The CDC has several critical programs related to health and extreme heat. One is the Natural Disasters and Severe Weather program's Extreme Heat site, which contains information about how to prevent heat-related illnesses and deaths. The National Institute for Occupational Safety and Health (NIOSH) program offers critical heat stress guidance, standards, and educational materials for workers who face the greatest heat risk. One of these is the Heat Safety Tool app, which uses real-time heat index and hourly forecasts to help plan outdoor work activities based on how hot it feels throughout the day (Figure 2.8).

Environmental Protection Agency (EPA). The EPA's Heat Island Reduction Program is one of the federal government's longest-running programs for urban heat planning. This program works with local officials, researchers, and community groups, providing strategies to help mitigate heat. The program offers a variety of resources and guides, recorded webinars, and a case study database.

Federal Emergency Management Agency (FEMA). FEMA provides disaster assistance as well as a variety of resources and funding opportunities for hazard mitigation planning. The Hazard Mitigation Grant Program requires communities to have a current hazard mitigation plan that identifies risks and actions to mitigate them. While hazards like flooding and wildfire have historically been the focus of hazard mitigation planning, heat is also a hazard that can be eligible for mitigation funds as long as its impacts and mitigation actions are included in the hazard mitigation plan. FEMA also runs the Building Resilient Infrastructure and Communities (BRIC) program to support communities undertaking hazard mitigation projects, which for heat mitigation could be expanded to include urban forestry or cool pavement. FEMA has several resources aimed at individual preparedness for extreme heat events.

Figure 2.8. CDC's Heat Safety Tool app provides real-time heat index and hourly forecasts to help improve the safety of outdoor activities (U.S. CDC)



Conditions are hazardous.

National Integrated Heat Health Information System (NIHHIS). NIHHIS is an integrated system developed jointly by NOAA and the CDC to help improve the national capacity, communication, and understanding of extreme heat. NIHHIS brings together a variety of agency resources and efforts related to urban heat, such as the Urban Heat Island Mapping Campaign, which has mapped urban heat islands in a number of cities across the country using satellite imagery and air temperatures.

U.S. Global Change Research Program (USGCRP). USGCRP is a federal program mandated by Congress that coordinates and integrates federal research on global and environmental change. One of USGCRP's central mandates is to develop the National Climate Assessment (NCA), which is the latest synthesis of climate science, impacts, and trends across U.S. regions and sectors. The NCA is aimed at improving decision-making and increasing resilience across the nation. While the USGCRP and NCA are focused broadly on all climate change aspects, they include various heat-related resources such as regional temperature projections and extreme heat-related impacts.

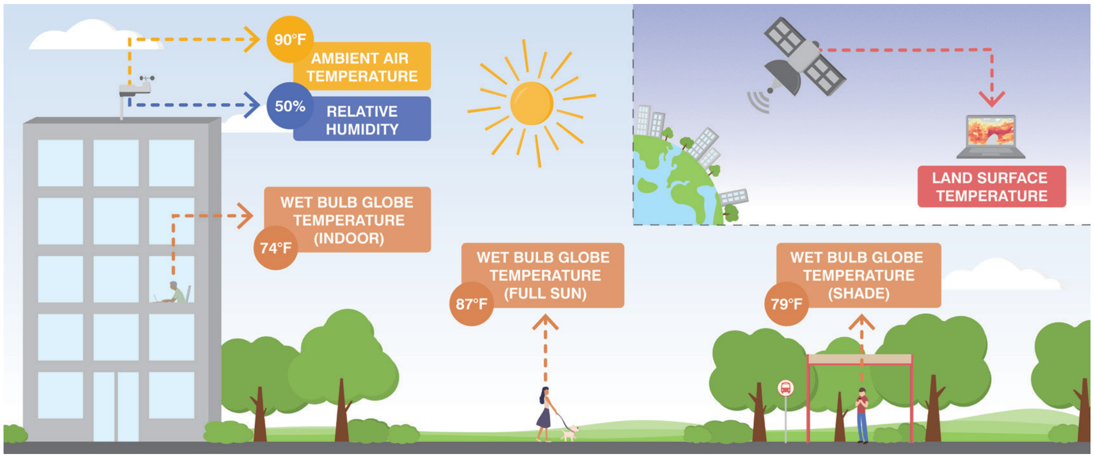


Figure 2.9. A multitude of measures exist for heat, including remote sensing of land surface temperatures, ambient air temperatures, and wet bulb globe temperature readings (Ladd Keith and Sara Meerow)

mitigation policies, and the Cool Roof Rating Council, which promotes methods for evaluating and labeling the effectiveness of roof and wall products.

In addition to international and national organizations, local NGOs often provide critical support and social services for communities at the highest heat risk. These include local nonprofits, grassroots organizations, and faith-based organizations that support the elderly, those with low incomes, and people experiencing homelessness. Involving local NGOs in emergency management planning can improve preparation for, and response to, extreme heat events.

Private Sector

The private sector can be involved in urban heat planning by collaboratively developing local heat planning strategies, assisting with education efforts, and implementing solutions.

Land developers, real estate financiers, private-sector planners, landscape architects, and architecture consultants all play critical roles in the future of the built environment and can provide valuable input to ensure that heat-related strategies are economically viable. Private-sector hospitals and healthcare providers similarly reach a large portion of the population and need to be included on the public health and emergency management side.

Energy Sector

The energy sector also plays a key role in urban heat resilience. Energy providers are responsible for the reliability of energy grid operations. Extreme heat events lead to increased air conditioning use, which strains energy operations.

With other climate risks increasing, such as wildfires and extreme storm events, it is more important than ever that energy grids are resilient and continue to operate. Power failures have already increased by more than 60 percent since 2015, and the possibility of a sustained blackout during an extreme heat event would have devastating consequences (Stone, Mallen, Rajput, Gronlund, et al. 2021).

URBAN HEAT INFORMATION SOURCES

Due to the complexity of urban heat and its impacts, no single information source can provide planners with everything they need to understand and plan for urban heat resilience. As shown in Figure 2.9, heat in the built environment can be measured in different ways, including satellite readings of land surface temperature that are used to create UHI maps, ambient air temperature readings used for weather forecasting, and wet bulb globe temperatures measuring human thermal comfort in different contexts. The complexity of heat requires planners to become more familiar with the various types of heat and how they can be measured depending on the circumstance.

Although urban heat planning is still an emerging area of practice, information sources to help advance urban heat resilience efforts are already widely available. Some of the most frequently used information sources include UHI maps, vegetation maps, vulnerability maps, historical and projected climate data, microclimate data, public health information, and heat outlooks and warnings (Meerow and Keith 2021). As with other information sources used to inform urban planning, each data source has limitations and appropriate uses, as detailed below.

LOCAL CLIMATE ZONES

Local climate zones (LCZs) are increasingly used by urban heat researchers and practitioners to better understand and model urban climatology based on land use and land cover derived from satellite remote sensing imagery (Stewart and Oke 2012).

The LCZ system comprises 17 zone types arranged by density, urban form, vegetation, type of land cover, and bodies of water. There are 10 built environment zone types, ranging from compact high-rise development through medium and low-rise development to sparsely built areas, and seven land cover zone types, ranging from dense trees through scrub to pavement, bare soil, or water areas. Each LCZ typology is correlated with urban climatology characteristics, such as heat severity. Similar to surface temperature urban heat island maps, LCZs should not be misinterpreted as reflecting diverse microclimate conditions and actual human thermal comfort experiences.

Although LCZs have been primarily used within heat modeling research to date, they hold promise for planning practice as another information source that planners can use to understand potential heat severity within their community based on land use and land cover. Planners can generate a map for their own community, such as those shown in Figure 2.10, using the LCZ Generator and interpret it with the user guide (Demuzere, Kittner, and Bechtel 2021).

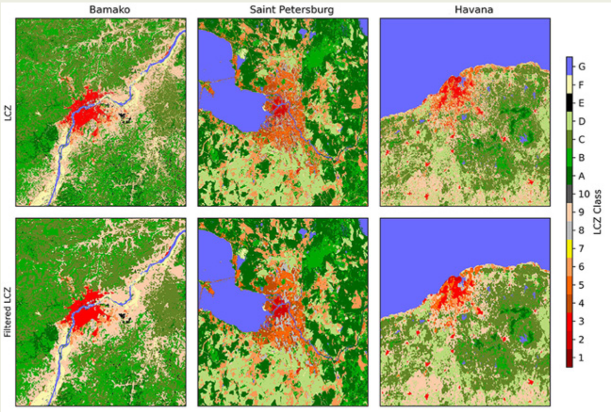


Figure 2.10. Local climate zones (LCZs) maps developed for Bamako, Mali; Saint Petersburg, Russia; and Havana, Cuba with original maps on the top row and filtered maps on the bottom row (Demuzere, Kittner, and Bechtel 2021 (CC BY 4.0))

Urban Heat Island Maps

UHI maps display areas of higher and lower heat severity within a community. They are usually derived from satellite remote sensing imagery and use reflectivity to estimate land surface temperatures. As with all satellite remote sensing imagery, it is important to know the time period used to create the map, as seasonality and climate variability, such as wet or dry years, can affect the heat severity displayed. Heat severity is also visualized differently on many UHI maps, which can make comparisons of heat severity between communities with diverse climates difficult.

It is also important to note that the surface UHI and land surface temperatures are not the same as the air temperature experienced by humans, which is more important for public health considerations (Venter, Chakraborty, and Lee 2021). In addition, these maps often only display the daytime surface UHI effect, and heat severity changes during the night also have public health consequences.

Despite this, satellite-derived UHI maps are becoming more widely available and can be a useful first step in helping a community identify areas with higher heat severity. The Trust for Public Land has developed a surface UHI map with the heat severity for every community in the United States (Figure 2.11).

Some UHI maps, such as those generated by the NIHHIS's Urban Heat Island Mapping Campaign, use ambient air temperature data in addition to satellite remote sensing imagery (Shandas et al. 2019). These maps can more closely reflect the ambient air temperatures experienced by humans.

UHI maps can help identify high heat severity areas, but they should not be the only data point used when prioritiz-

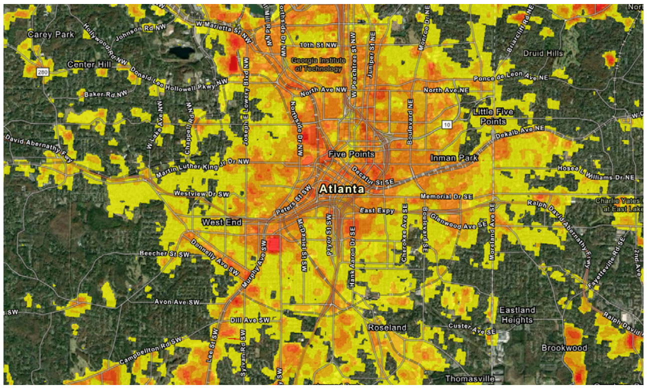


Figure 2.11. UHI map for Atlanta showing areas with higher (yellow) to highest (red) heat severities (The Trust for Public Land)

ing and locating heat mitigation or management strategies. Where maps showing relative temperatures are not available, or to add an additional source of information, local climate zones (LCZs) may be calculated based on satellite-derived land-use and land cover maps and used to identify hotter areas, as described in the sidebar on p. 27.

Vegetation Maps

Vegetation maps can be a useful data source, considering the well-documented relationship between the amount of vegetation and cooler areas in communities and the popularity of urban greening as a heat mitigation strategy. These maps can help determine areas with higher and lower amounts of green space, vegetation, and urban forests.

Remote sensing imagery derived from satellites like Landsat can be used to estimate vegetation maps over a large urban area, down to the level of tree species type and number. Vegetation maps derived from satellite remote sensing imagery can be developed in many ways, so it is important to know what date range the map displays and the area's seasonality of tree cover and vegetation changes, as well as whether it came from a year with lower, average, or higher precipitation than usual.

Urban forestry maps can also be developed with actual tree counts by trained staff or crowdsourcing through citizen scientists. These maps contain more specific information about tree species, age, and health but must be regularly updated as vegetation changes.

The U.S. Forest Service offers information on developing a local urban tree canopy assessment. American Forests has piloted a Tree Equity Score that uses both tree canopy and socioeconomic data to identify areas of greatest vegetation improvement need for U.S. cities (Figure 2.12).

Heat Vulnerability Maps

Heat vulnerability maps are an important data source to ensure urban heat planning efforts target the areas of greatest need. They can be used to help prioritize locations for future cooling centers, urban greening, housing weatherization improvements, or education and information campaigns.

These maps typically display the location of estimated heat vulnerability derived from U.S. Census demographic characteristics, such as income, minority status, housing, and transportation, which research suggests are associated with a higher risk of negative heat effects. The U.S. CDC Social Vulnerability Index (U.S. CDC 2022) is a customizable tool available for every census tract in the country. NIHHIS has developed the Future Heat Events and Social Vulnerability tool, which is focused on heat vulnerability.

As heat vulnerability factors vary by community and purpose, some states and local governments have begun developing their own heat vulnerability maps tailored to local characteristics. For example, Harris County Public Health, which serves the Houston area, has developed an Extreme Heat Vulnerability Assessment (Figure 2.13) (Harris County Public Health n.d.). The assessment and corresponding map use health, economic, governmental, community, and environmental indicators to create a vulnerability score for each census tract.

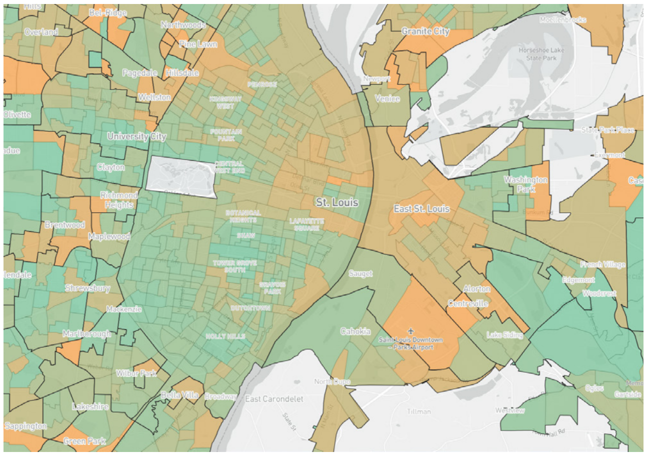


Figure 2.12. The Tree Equity Score for St. Louis, Missouri, showing areas with higher tree canopy inequity in orange (American Forests)

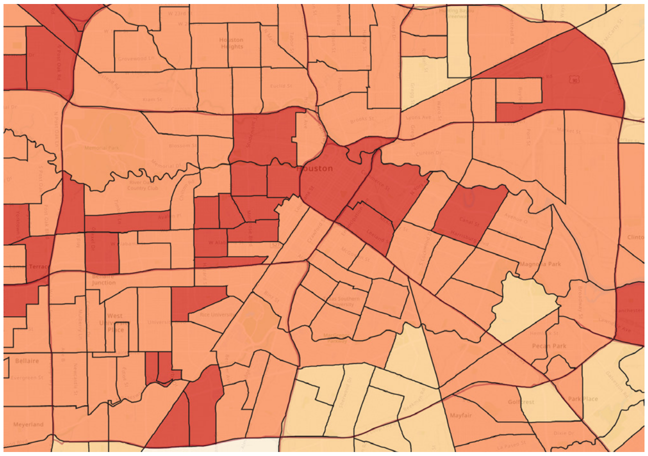


Figure 2.13. Harris County's Extreme Heat Vulnerability Assessment map, showing areas in Houston with higher heat vulnerability in red (Harris County)

Historical and Projected Climate Data

Historical and projected climate data for an area can be very useful in planning for urban heat by demonstrating what conditions have occurred in the past and what changes are projected for the future. Historical climate data includes temperature, humidity, wind, and precipitation.

This information is often accessible through local NWS offices and is nationally archived by the [NOAA National Centers for Environmental Information](). Historical climate data is typically recorded at a single or a limited number of weather stations, such as at a regional airport; however, as such, it does not reflect the complexity of localized temperatures due to factors like geography and the UHI effect.

Understanding an area's historical climate data can help show what has occurred in the past, but climate change is rapidly shifting average annual temperatures. Climate change projections are critical to understanding an area's future projected climate.

Climate change projections are modeled at the global scale and then downscaled to the regional and sometimes local levels. Global climate change models used since the 1970s have accurately predicted the range of increase in average temperatures observed (Flato et al. 2013). Climate change models use assumptions about how quickly greenhouse gas emissions will be mitigated or if they will continue to increase. Due to this uncertainty about emissions reductions, climate change projections are often shown under different emissions scenarios.

The National Climate Assessment (USGCRP 2018) provides national and regional temperature increase projections as well as climate impacts. The U.S Climate Explorer is another federal resource with graphics and maps of both historical and projected climate variables for every county, such as projected increases in temperature (Figure 2.14).

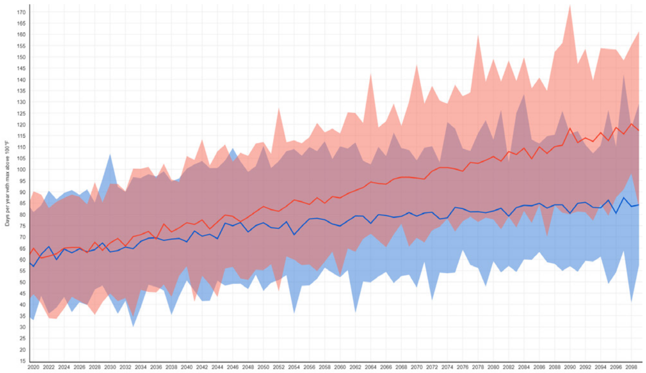


Figure 2.14. Projected increase in days with a maximum temperature above 100°F (37.8°C) for Las Vegas under low emission (blue) and high emission (red) scenarios (U.S. Climate Explorer)

Microclimate Data

Thermal comfort is heavily influenced by microclimate, which, in turn, is heavily influenced by the design of a site.

Microclimate data can be collected and analyzed to improve thermal comfort at the site level. This includes using portable ambient air temperature or WBGT devices, infrared thermometers to measure surface temperatures, and cameras that can capture forward-looking infrared thermal images to display cool and hot locations in an area (Figure 2.15, p. 30). Readings can be captured at various times throughout the day and night and under shade versus in the full sun.

While this can be time intensive and may require new partnerships between communities and researchers who have heat sensors, the information can lead to a better understanding of local design characteristics that can improve thermal comfort (Turner et al. 2022). This can be particularly useful for highly used public spaces, such as downtowns, main streets, schools, parks, and pedestrian routes.

Public Health Information

County and state health departments collect various types of public health information that can be helpful to planners considering heat risk, although the types of health information collected and the methodology tends to vary by location.

As heat compounds existing physical and mental health issues, public health information on the areas of a community with the highest health disparities is useful for urban heat planning. The numbers and locations of heat-related illnesses, hospitalizations, and deaths can also be central to urban heat planning efforts and provide important indicators of whether heat mitigation and management efforts are succeeding. Planners should keep in mind, however, that while the accuracy of heat-related illness and death reporting is slowly improving in some areas, these cases are most often greatly underreported (Gubernot, Anderson, and Hunting 2014; Ostro et al. 2009).

Heat Outlooks and Warnings

Heat outlooks and warnings are critical for emergency managers, public health officials, and community members

Figure 2.15. Thermal image (right) taken in Las Cruces, New Mexico, showing hotter areas in brighter colors with cooler areas in darker colors, with temperatures displayed in Fahrenheit (Dave DuBois/U.S. NOAA)

in preparing and responding to extreme heat events. NWS issues these alerts in coordination with local offices, as certain heat index thresholds are common in some locations and more dangerous in others. Heat outlooks and watches give notice of potential extreme heat events, while heat warnings and advisories mean dangerous heat conditions are imminent or in progress.

The NWS also has an experimental HeatRisk product, offered as a supplement to its official heat watch/warning/advisory program, to help identify potential upcoming risks in each seven-day weather forecast.

Other Information Sources

In addition to the heat-related information sources presented above, other commonly used planning information sources may be helpful for understanding and addressing urban heat.

- **Housing quality data** that includes age of the structure and presence or absence of air conditioning can help identify neighborhoods for weatherization assistance programs.
- **Transportation, transit, pedestrian, and bicycling usage information** can be used to help prioritize cool corridors that have consistent shade cover.
- **Long-range planning for growth or conservation areas** can help identify and better protect natural or rural areas that provide a cooling effect for an urbanized region.
- **Sociodemographic data and information**, such as the location of marginalized communities, can help prioritize urban heat actions to the communities of greatest need.

As the threat of extreme heat becomes more widely recognized and extensively studied, more accessible and targeted data sources for heat planning should become available. But as the threat of extreme heat increases, urban planners should begin or advance their community's urban heat resilience efforts with the information that can be obtained today.

CONCLUSION

Urban heat is an increasing risk due to the UHI effect and climate change, which together are increasing average temperatures as well as the increased likelihood, duration, and severity of extreme heat events. There are complex interactions between the larger-scale UHI effect and site level microclimates, which in turn influence human thermal comfort and the resulting experience of heat.

Although urban heat lacks a governance structure when compared to other climate risks, planners can play a central role if they coordinate with other local government practitioners, including emergency management, hazard mitigation, and public health officials. There are also multiple federal agencies with critical resources and guidance available that planners can tap into, including NOAA, EPA, CDC, and FEMA as well as the cross-cutting NIHHIS and USGRCP programs.

While information sources for urban heat are rapidly evolving and improving, there is already a wide variety of information sources available to all communities in the United States to help planners start or advance urban heat planning efforts. As urban heat affects marginalized and disenfranchised communities the most, urban heat planning efforts should center on equitable solutions. The next chapter discusses the planning profession's role in historical heat inequities and outlines how to center equity in urban heat resilience planning efforts.

CHAPTER 3

EQUITY AND URBAN HEAT

While all communities face increasing temperatures, heat is often experienced very differently by community members. Heat severity is not equitably distributed, as areas with lower-income, minority, and marginalized community members are often hotter than their wealthier and whiter counterparts. These areas also frequently have lower-quality housing, less effective indoor cooling, and less reliable transportation options. Heat inequity is an environmental justice issue.

Heat compounds existing socioeconomic and health concerns faced by these same community members. While extreme heat events such as heat waves can draw the public's attention, chronic urban heat also has detrimental health consequences for high-risk community members. If planners understand the historical and current factors that have led to these inequities, they can better prioritize heat planning strategies to redress them.

This chapter addresses how past urban planning has contributed to current heat inequities. It explains the racial and spatial inequities of urban heat and how historical racially discriminatory policies, such as redlining, contributed to those inequities. This chapter also discusses the professional and ethical responsibilities of planners to address these inequities and advance urban heat resilience for all community members.

THE INEQUITABLE DISTRIBUTION OF URBAN HEAT

Heat exposure is not evenly or equitably distributed across communities. Inequities in urban heat are due to the uneven distribution of heat within the built urban environment and varying levels of vulnerability among populations within a community (Mitchell and Chakraborty 2014).

Some neighborhoods are hotter than others due to characteristics of the built environment, such as lack of vegetation and the high percentage of impervious surfaces. Additionally, some community members have higher exposure because they must spend more time outdoors, such as those experiencing homelessness (Figure 3.1, p. 33) (Putnam et al. 2018). The causes of increasing heat are also inequitable as the wealthy contribute proportionately more to climate change and the urban heat island (UHI) effect, but heat has the greatest impact on those with lower incomes (Thomas and Butters 2018).

The characteristics of the built environment are often inextricably tied to income level and minority status. One study of land cover patterns across U.S. Census blocks found non-Hispanic Blacks 52 percent more likely, non-Hispanic Asians 32 percent more likely, and Hispanics 21 percent more likely than whites to live in areas with land cover qualities related to higher heat severity (Jesdale, Morello-Frosch, and Cushing 2013).

Another study found that in six of the 175 largest urbanized areas in the United States, the average person of color lives in a neighborhood with a higher UHI effect than non-Hispanic whites. The same was true for those living below the poverty line compared with those twice above the poverty line (Hsu et al. 2021). Finally, a study of 20 urban areas in the Southwest found that areas home to the poorest 10 percent of residents were 4°F (2.2°C) hotter on average than the wealthiest neighborhoods of the same area (Dialesandro et al. 2021).

As heat is a compounding risk, it poses a greater threat to communities with other socioeconomic and health risks. Extreme heat events can decrease air quality, and those with respiratory conditions can become more sensitive to poor air quality in higher temperatures (Papanastasiou, Melas, and Kambezidis 2015). An example of this is wildfire smoke, which can travel hundreds or thousands of miles across the United States. In a high-heat situation, those with inadequate indoor cooling can be faced with a decision to close the

Figure 3.1. People experiencing homelessness, such as the inhabitant of this tent on an Austin, Texas, sidewalk, often face heat risk throughout both the day and the night (Adam Thomas/Unsplash)

windows and suffer from the heat or open the windows and suffer from poor air quality. Poverty has been shown to be a key determinant of heat-related or heat-caused deaths due to lack of medical care and resources (Balbus and Malina 2009).

The Legacy of Discriminatory Planning on Urban Heat

The differences in the UHI effect commonly observed across communities often have their roots in historical discriminatory planning practices, the legacy of which continues to influence the built environment and heat severity today.

Several studies have documented the legacy of redlining on urban heat (Figure 3.2, p. 34). Redlining is the discriminatory practice of denying financial and other services to residents of certain areas based on race or ethnicity. Maps of urban areas created in the 1930s by the Home Owners' Loan Corporation (HOLC), a federal agency, graded neighborhoods based on the degree of perceived financial risk. Neighborhoods comprising mostly white residents received "A" or "B" grades of "best" or "still desirable" and residents had free access to mortgages and other financial tools. Meanwhile, neighborhoods with minority residents were assigned "C" or "D" grades—"definitely declining" or "hazardous"—and banks refused to give loans in those areas, making homeownership or even home maintenance difficult or impossible for minority residents (Nelson et al. 2022).

One study of formerly redlined areas in Baltimore, Dallas, and Kansas City, Missouri, found that those areas targeted for disinvestment had higher land surface temperatures than non-redlined neighborhoods due to differences in characteristics of the built environment and vegetation (Wilson 2020). Another study of 108 urban areas in the United States found that 94 percent of redlined neighborhoods had higher land surface temperatures, up to 12.6°F (7°C), than non-redlined neighborhoods (Figure 3.2) (Hoffman, Shandas, and Pendleton 2020). These formerly redlined neighborhoods are often still primarily home to minorities and often lack public investment, which tends to be prioritized for other areas.

Other discriminatory planning practices in the past have also contributed to the current inequitable arrangement of the built environment and the associated UHI effect. Locally unwanted land uses (LULUs) that tend to increase heat severity have been historically placed in neighborhoods with a larger share of lower-income, minority, and marginalized community members that do not have the political power to fight them off. Major highway infrastructure was notoriously routed through lower-income and minority neighborhoods, resulting in higher heat severity in those areas today. Other LULUs that can result in higher heat severity include landfills, power stations, airports, and large institutional facilities, such as hospitals or prisons.

In addition, a long history of disinvestment in certain neighborhoods has resulted in lower-quality housing stock, which is often less energy efficient, and this translates to higher indoor cooling costs. Research indicates that minority households in the United States have higher energy costs and are more likely to face energy poverty, or struggle to meet energy needs (Goldstein, Reames, and Newell 2022; Bednar and Reames 2020). Tribal communities also have unmet energy needs and face challenges in the

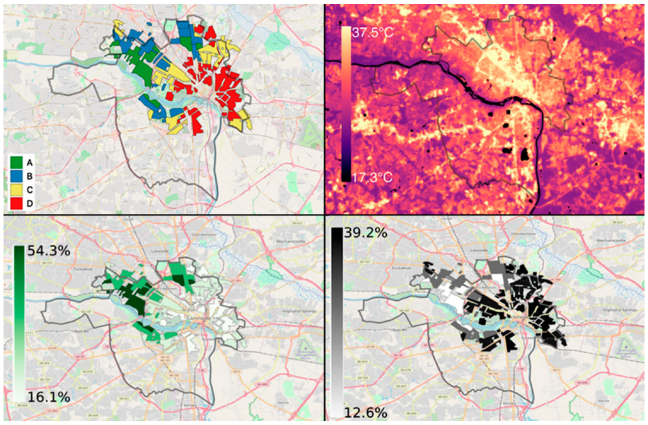


Figure 3.2. The Richmond historic redlining map compared against heat severity shows how redlining practices have resulted in heat inequities that persist to this day. The top left map shows the historic HOLC security grades. The top right map shows 2016 land surface temperatures, the bottom left map depicts the percent tree canopy, and bottom right map shows the average percent impervious surface in those areas (Jeremy Hoffman (CC BY 4.0))

development of energy sources that are self-directed, reliable, and accessible for tribal members (USGCRP 2018).

PLANNING FOR HEAT EQUITY

Heat equity is the right of all community members to have thermally safe indoor and outdoor environments. It is sometimes addressed as part of a broader focus on *thermal equity*, which includes heat and cold. Heat equity includes heat experienced by people in their homes, places of education, work, shops, services, and recreation, and throughout their travel to and from these places.

Planners have a responsibility to equitably address urban heat. The [AICP Code of Ethics and Professional Conduct]() states that planners shall

> *seek social justice by identifying and working to expand choice and opportunity for all persons, emphasizing our special responsibility to plan with those who have been marginalized or disadvantaged and to promote racial and economic equity. Urge the alteration of policies, institutions, and decisions that do not help meet their needs.* (3.3)

> *Recognize and work to mitigate the impacts of existing plans and procedures that result in patterns of discrimination, displacement, or environmental injustice. Plan for anticipated public and private sector investment in historically low-income neighborhoods to ensure benefits defined by the local community. Promote an increase in the supply and quality of affordable housing and improved services and facilities with equal access for all residents, including people with disabilities.* (3.4)

Though the AICP Code of Ethics is binding only for AICP-certified planners, these aspirational principles should be upheld by all planners as foundational for the profession.

It is important to act now because heat already disproportionately threatens the health and well-being of some communities today, and these risks are likely to increase in the future. The planning profession is implicated in past decisions that have resulted in some neighborhoods being hotter than others, but planners today can proactively redress these disparities.

Incorporating Equity in Urban Heat Resilience

Heat equity is a central component of planning for urban heat resilience. Drawing from Meerow, Pajouhesh, and Miller's (2019) framework of social equity in urban resilience, planners should incorporate heat equity into urban heat resilience through equitable distribution, recognition, and procedures as described below.

- **Distribution.** Planners should ensure that urban heat resilience efforts are equitably distributed across the community, meaning that efforts help those with the greatest heat vulnerability. This includes equitable distribution of heat mitigation strategies to reduce the UHI effect and heat management strategies to prepare for and respond to extreme heat events.
- **Recognition.** Planners should acknowledge and respect the history and needs of different groups when planning for urban heat resilience. Awareness, perception, concerns, and immediate needs related to heat risk can be very different across a community.
- **Procedures.** Finally, planners should engage community members in equitable participation in decision-making processes. This includes participation in plan develop-ment and implementation with a focus on outreach to traditionally marginalized groups. As described above, the planning profession historically had a role in the current heat severity in low-income

and minority neighborhoods and must work to redress that injustice with meaningful engagement.

In short, heat equity will mean not only ensuring that heat risks and mitigation strategies are fairly distributed but also recognizing that historically they have not been, and therefore customizing strategies to the needs of different communities. Community members should be part of the process of developing, researching, and implementing those strategies, even if this engagement takes time (Guardaro et al. 2020; Ziegler et al. 2019).

Heat Equity Planning Functional Areas

Heat equity intersects with many relevant planning specializations. In addition to implementing the heat mitigation and management strategies covered in Chapters 5 and 6 to address thermal equity, planners should integrate heat equity into the following areas of planning practice.

- **Land use.** Current development review and long-range planning for land use are two of the planning profession's key responsibilities. Land-use planning shapes the built environment and therefore shapes the UHI effect and which areas have the highest heat severity. Planners should incorporate heat equity into land-use planning to help mitigate heat severity, particularly in lower-income, minority, and marginalized areas. Heat impacts could also be incorporated into environmental review processes for new development.
- **Infrastructure.** Urban infrastructure—everything from public buildings, the energy grid, and telecommunications to roadways, sidewalks, and transit stations—is adversely impacted by heat. Communities in the United States also have a history of infrastructure disinvestment in lower-income and minority communities, meaning the infrastructure impacted by heat in these areas is often already inadequate. Planners should consider the inequitable distribution of higher heat severity across a community when planning infrastructure.
- **Energy.** Expensive utility bills can be a major barrier to the use of indoor cooling by those with lower incomes. Affordable, accessible, and reliable energy for indoor cooling is a key requirement of heat equity. Some states prohibit energy shutoffs due to lack of payment in summer months, but this can be a concern in states that do not regulate energy shutoffs. Addressing disparities in household energy efficiency can also help to reduce energy poverty. Finally, it is important to ensure that critical facilities with vulnerable community members, such as hospitals and nursing homes, have backup power sources so indoor cooling continues to function during a power outage.
- **Housing.** The quality, affordability, and availability of housing is a growing equity concern in the United States, where housing is becoming out of reach even for many considered to be in the middle class. Housing quality, including insulation, indoor cooling, and surrounding vegetation, directly affects the thermal comfort of occupants. Disenfranchised neighborhoods often have older housing of poorer quality. They also have higher rental rates, which can make it more difficult for occupants to make modifications based on their personal thermal comfort experiences, while landlords often lack incentives to increase efficiency because they pass on utility costs to tenants.
- **Natural resources.** The built environment and waste heat that contribute to the UHI effect are both outcomes of urban development in previously agricultural, rural, and natural areas. Conserving agricultural and natural areas is an important component of mitigating the UHI effect caused by continued urban sprawl. Planners should consider equity considerations of smaller towns and rural communities facing urban growth pressures.
- **Parks and recreation.** The inequitable distribution, size, and amenities of parks for lower-income neighborhoods is another consideration for planners. Parks with amenities such as constructed shade structures, well-placed trees, and water features like splashpads can provide outdoor respite space during high temperatures, as well as decrease temperatures due to the UHI effect. Shaded and vegetated greenways and urban trail systems can also help create ventilation corridors that cool nearby neighborhoods. When planning new vegetation, green infrastructure, or parks, it is important to address concerns that they will lead to green gentrification.
- **Transportation.** Planners should consider the entire transportation system to be a key component of a community's thermal equity. Street networks, together with parking lots, are one of the biggest contributors to the UHI effect due to the amount of asphalt and concrete they add to the built environment. The placement of transportation systems, such as interstate highways, is connected to inequitable higher heat severities. These systems also often have other compounding health impacts on lower-income and minority communities,

> such as lower air quality. Planners can incorporate the concept of "cool corridors," which are highly shaded streets to serve pedestrians, bicyclists, and vehicles. Transit systems can sometimes underserve communities with high heat risk—for example, by forcing riders to wait long periods in the heat. Planners can help ensure that transit is reliable and that riders have shaded stations or stops, particularly in areas of high heat severity.

Planners who work on infrastructure, housing, natural resources, parks and recreation, and transportation should incorporate the thermal equity considerations discussed above into their planning and decision-making processes. Chapter 7 also discusses the importance of engaging communities in developing more equitable heat solutions.

CONCLUSION

To be able to effectively address the increasing impacts of extreme heat within their communities, planners must understand the inequities of urban heat, which often compound existing socioeconomic and health factors. Planners historically played a role in shaping those inequities through unjust practices such as redlining and the placement of LULUs such as highways, institutional facilities, and other heat-increasing land uses. Planners have a responsibility to redress these by ensuring that all community members have heat equity: access to thermally safe indoor and outdoor environments.

Planners can ensure that heat equity is incorporated into urban heat resilience planning by considering the distribution of efforts, recognizing and acknowledging past injustices, and engaging all community members—particularly historically marginalized groups—in public participation and decision-making processes. Planners should consider heat equity when working across many functional areas of planning, including land use, infrastructure, energy, housing, natural resources, parks and recreation, and transportation.

The critical consideration of heat equity highlighted in this chapter informs the practical framework for planning for urban heat resilience that is laid out in the following chapter. Specific and actionable heat mitigation and management strategies are described in Chapters 5 and 6, followed by planning tools and processes in Chapter 7.

CHAPTER 4

URBAN HEAT RESILIENCE PLANNING FRAMEWORK

Working towards urban heat resilience requires proactive and equitable planning of both heat mitigation and management. Heat planning is in the early stages in most communities, but published work on climate change planning more broadly offers guidance on what principles should form the basis for effective heat resilience planning.

This chapter outlines seven practical considerations for holistically addressing urban heat resilience in planning (Figure 4.1, p. 39):

1. Setting clear urban heat planning goals and associated metrics for success
2. Building a comprehensive “fact base” of information on heat risks
3. Developing a diverse portfolio of heat mitigation and management strategies
4. Managing uncertainty
5. Coordination across planning efforts
6. Inclusive participation in planning processes
7. Effective implementation, monitoring, and evaluation

This list is based upon seven principles that underlie strong climate change planning (Meerow and Woodruff 2019).

This chapter provides an overview of each principle and its application to heat resilience planning. These principles are also demonstrated in two case study cities at the forefront of heat planning in the United States, New York City and Phoenix, as described in the sidebars on pp. 45 and 46, respectively. Finally, the chapter introduces the Plan Integration Scorecard for Resilience for Heat (PIRSH), a new method for assessing and improving the integration of heat strategies across community plans.

SETTING URBAN HEAT GOALS

In the face of growing urban heat risks, planners should work with their communities to establish heat resilience goals. As noted in Chapter 1, heat resilience is an inclusive term that describes efforts undertaken at a local level to both prepare for and adapt to extreme heat risks.

Goals should be ambitious enough to meet the scope of the urban heat challenge but also achievable. Planners should include goals related to both *heat mitigation* (cooling communities through vegetation or design of the built environment) and *heat management* (reducing heat risks through emergency response or social services) strategies that their communities undertake.

Metrics for Success

All heat resilience goals should be linked to specific, measurable outcomes, which should be linked to metrics of success. There are many possible metrics to use, depending on the context of the community.

One potential heat mitigation metric is the reduction in measured heat severity in neighborhoods over time, which can be measured through air temperature sensors or land surface temperature maps. In addition, because of the well-documented inverse relationship between vegetation and heat (Ibsen et al. 2021) and the popularity of urban greening as a heat mitigation strategy, cities may want to measure and set goals for vegetation cover. This can be monitored using readily available remotely sensed (satellite) data (e.g., using a normalized difference vegetation index (NDVI)). Some communities have also assessed and set targets for an increase in percent tree canopy cover for either the whole community or specific neighborhoods that have lower levels.

Heat management metrics include the number of heat-related illnesses, hospital visits, and deaths. Although these numbers are often underreported, they can still provide planners with a baseline metric to begin tracking. Because

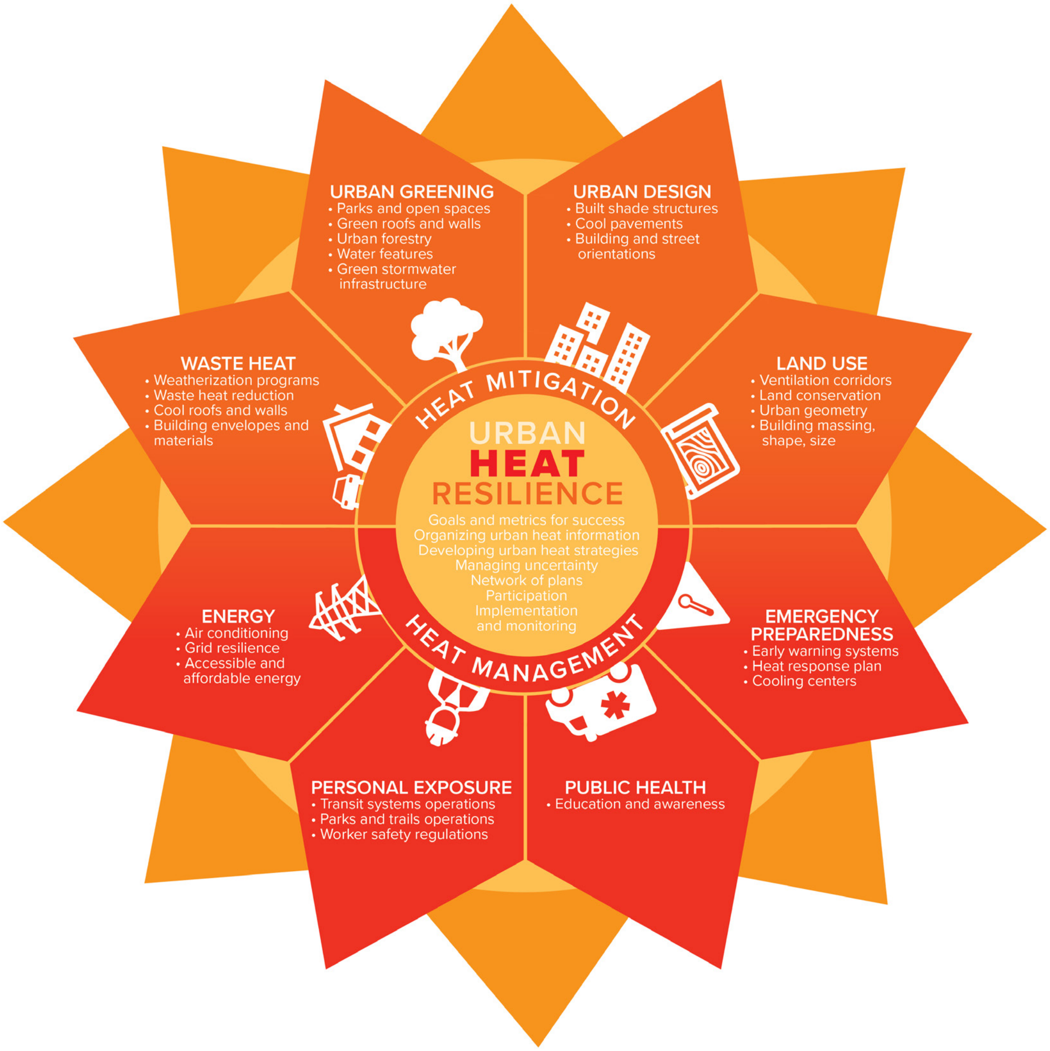


Figure 4.1. Urban heat resilience strategies (Ladd Keith and Sara Meerow; adapted from Meerow and Keith 2021)

of the importance of cooling centers in preventing heat illnesses and deaths, planners could also analyze how much of the overall population or specific vulnerable community members are within a walkable half-mile of a cooling center.

ORGANIZING URBAN HEAT INFORMATION

To set goals and strategically develop urban heat mitigation and management strategies to achieve them, communities need a strong heat fact base—that is, they need to gather information on current and future urban heat risks.

As discussed in Chapter 2, this would ideally include information on historical temperatures, maps of the current UHI effect, heat vulnerability and demographic data, and future climate projections for heat. Planners should collect the relevant information from available sources and integrate it into a web application or plan to help their communities comprehensively understand current and future urban heat planning needs. Figure 4.2 (p. 40) shows an example of the Resiliency Planning Map, a publicly accessible web application created by the Pima Association of Governments, the metropolitan planning organization for the greater Tucson region in Arizona. The

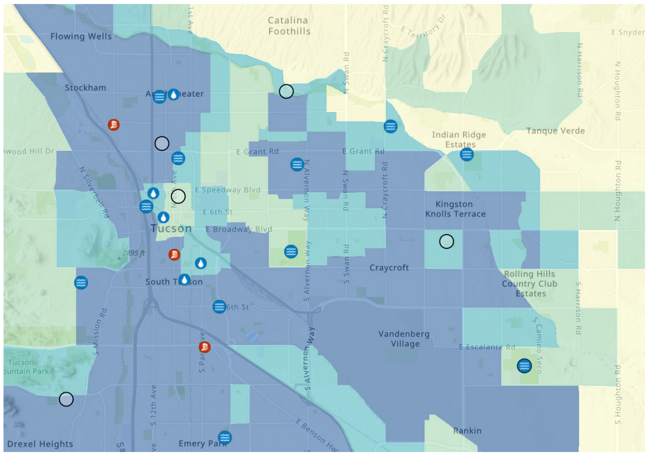


Figure 4.2. The Resiliency Planning Map for the Tucson region showing the "Heat Impacts and Relief" layers of social vulnerability, indicated by darker blue shading, and locations of cooling centers, splashpads, and pools (Pima Association of Governments)

"Heat Impacts and Relief" map layers include heat severity, the CDC social vulnerability index, and the locations of cooling centers, splashpads, and pools.

DEVELOPING URBAN HEAT STRATEGIES

Planners should use the information on heat risks to develop a diverse portfolio of heat resilience strategies targeting the communities where they are most needed.

A comprehensive approach to planning for urban heat resilience combines heat mitigation and heat management strategies.

- **Heat mitigation strategies** aim to reduce the built environment's contribution to extreme heat through design and planning interventions such as land-use policies, urban design, urban greening, and waste heat.
- **Heat management strategies** aim to prepare for and respond to extreme heat, and address energy, personal exposure, public health, and emergency preparedness.

Examples of these strategies are provided in detail in Chapter 5 (heat mitigation) and Chapter 6 (heat management) of this report.

When selecting a portfolio of diverse heat strategies, planners should consider whether any of them have co-benefits and tradeoffs and avoid strategies that may be maladaptive. Some strategies that address urban heat can also address other hazards and serve other functions. It is strategic to leverage these co-benefits, or win-wins, as they maximize limited resources. For example, vegetated green infrastructure is widely promoted as a stormwater management solution and can also mitigate heat (Whitman and Eisenhauer 2020). Programs and regulations that increase energy efficiency can help mitigate waste heat, a component of the UHI effect. Energy efficiency strategies also decrease greenhouse gas emissions from energy production and reduce a community's contribution to future climate change.

While it is valuable to prioritize strategies with co-benefits, it is also important to minimize tradeoffs. For example, increasing vegetation may effectively mitigate heat in arid cities, but this has to be weighed against increased water use (Gober et al. 2010). Because urban heat is complex (as discussed in Chapter 2), there may be tradeoffs in how strategies affect different aspects of the thermal environment. For example, research suggests that solar-reflective pavements in Los Angeles can help to reduce surface temperatures, but they may increase experienced heat (mean radiant temperature) for people walking on them (Middel et al. 2020).

Planners should avoid maladaptive heat mitigation and management strategies. Maladaptation is defined as an "action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups" (Barnett and O'Neill 2010). An often-cited example of a maladaptive strategy for growing heat risk is widespread use of inefficient air-conditioning units in energy-inefficient buildings that both increase waste heat and are powered by fossil fuels, which in turn worsen climate change. Increased and equitable adoption of air conditioning is needed in many communities, however, and air conditioning is not inherently maladaptive. Air conditioning access for vulnerable community members could be expanded without increasing greenhouse gas emissions through stricter energy efficiency standards for nonresidential buildings, subsidies for more efficient air conditioning units, building weatherization programs, and decarbonization of the energy sector (e.g., promotion of renewable energy). During a heat wave in New York City in 2019, for example, the mayor called for city government buildings and private offices to raise thermostats to help manage demand on energy supplies, but also provided certain vulnerable community members with free air conditioners.

While it is helpful to propose a wide range of strategies, they should be prioritized based on transparent criteria such as cost-benefit analysis or community preferences. As with all planning topics, the selection of strategies is a complex process of balancing evidence-based decision-making with community values and preferences. When resources become available, this makes it easier to decide what to implement, and conversely, when resources are scarce, they can be allocated to the most critical strategies first.

MANAGING UNCERTAINTY

Planning for urban heat requires planners to manage considerable uncertainty (Corburn 2009). The past is no longer a good predictor of future temperatures or extreme heat events due to increasing climate change and the UHI effect. Climate models provide future climate projections, but because of the complexity of the climate system, different models show different results. Additionally, future climate depends on the actions globally taken to reduce greenhouse gas emissions, while a community's future UHI effect depends on urban development trends and behavior. Therefore, the recommended practice for climate change, and more specifically, for urban heat planning, is to show temperature changes under a variety of scenarios (Stults and Larsen 2018).

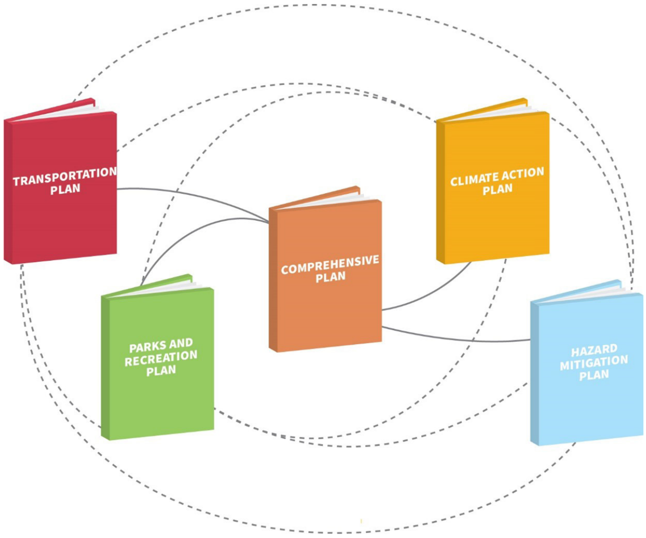


Figure 4.3. A "network of plans" relevant to urban heat resilience (Ladd Keith and Sara Meerow)

Because of the complexity and variability of urban climates and cities more broadly, it can be difficult to predict the effectiveness of different strategies. Local conditions are also key. For example, research suggests that vegetation has a greater cooling effect in arid cities, so an urban forestry strategy that works well in Las Vegas may not necessarily work as well in Miami (Ibsen et al. 2021).

Planners should try to recognize sources of uncertainty and select strategies that will be beneficial under a variety of different futures wherever possible. It may be especially useful for planners to identify both "no-regret" strategies that would presumably be beneficial regardless of future heat risk, as well as "low-regret" strategies that are beneficial now and under multiple (though not necessarily all) future climate scenarios (Stults and Larsen 2018). Scenario planning could be helpful in identifying which strategies are low- or no-regret.

As part of the Central Arizona-Phoenix Long-Term Ecological Research program, researchers developed a set of alternative future scenarios for the greater Phoenix metropolitan area in 2060, including one scenario specifically focused on reducing heat exposure (Iwaniec et al. 2020). While strategies differed across the scenarios, they all made greater use of alternative sources of water, such as rainwater harvesting, gray water systems, or reclaimed water. It might therefore make sense for the region to prioritize these strategies as seemingly no-regret options.

ADDRESSING URBAN HEAT ACROSS THE NETWORK OF PLANS

Planners should integrate urban heat resilience into the many community plans that shape urban development, including comprehensive plans, small area plans, infrastructure plans, and open space plans.

A "network of plans" (Figure 4.3) refers to the suite of local comprehensive, functional, and small area plans that collectively shape urban development (Berke et al. 2015). This is particularly important for heat planning because, as discussed in Chapter 2, the built environment greatly influences urban heat risk.

As illustrated in Figure 4.4 (p. 42), a city's comprehensive plan generally outlines the overall vision for the community, including an objective of reducing

Figure 4.4. The various community plans within the network of plans each shape different aspects of the built environment and impact heat risk (Ladd Keith and Sara Meerow)

heat risk. The parks and recreation plan might call for new green space and tree planting, which would help to mitigate heat. Similarly, a hazard mitigation plan might propose green stormwater infrastructure projects that would also support vegetation. A climate action plan could promote green walls and roofs that further mitigate heat and rooftop solar energy, which would reduce waste heat. Meanwhile, a transportation plan could propose road expansions and new surface parking lots that might increase the UHI effect, thereby negating some of the cooling benefits in other plans.

Heat planning efforts may be consolidated in a heat-specific plan or integrated into other existing plan types. If a community chooses the latter approach, different heat mitigation and management strategies will likely fit best in different types of plans. For example, a comprehensive plan could call for the amendment of building codes to require cool or more reflective roofs. Efforts to expand tree canopy might be best outlined in a sustainability or urban forestry plan. The establishment of cooling centers for extreme heat events may be best laid out in an emergency management plan. Cities could include heat as one of the hazards addressed in a hazard mitigation or climate change adaptation plan. Chapter 7 will discuss in more detail the relevant types of community plans and how they can address heat.

Regardless of whether a city develops a specific plan for urban heat or includes heat resilience strategies across its network of plans, planners should integrate these efforts to avoid working at cross-purposes. Planners widely agree that plan integration is important for enhancing community resilience, and heat is no exception (Gomez 2020). The potentially synergistic or contradictory heat impacts of different plans need to be acknowledged and ideally coordinated. One way for a community to assess integration across plans and identify specific areas for improvement is to use the Plan Integration for Resilience Scorecard for Heat (PIRSH), as discussed in the sidebar on p. 43.

PARTICIPATION IN URBAN HEAT PLANNING

Urban heat planning requires coordination across different levels of government and local government departments and the engagement of community stakeholders to be successful.

Heat mitigation efforts will likely closely involve planners; departments of public works, parks and recreation, and transportation; utilities; nonprofits focused on expanding nature-based solutions, such as The Nature Conservancy or The Trust for Public Land; and private developers. Heat management efforts require the coordination of public health and emergency management departments, first responders, energy providers, and community-based organizations. Dedicated heat staff, including recently appointed chief heat officers in communities such as Miami, may help coordinate these different actors and efforts, and planners would be well positioned to serve in these roles in the future.

Because of the well-documented inequities in urban heat risk discussed in Chapter 3, it is essential to thoughtfully engage marginalized communities in heat planning. Local knowledge from these communities can improve planning by bringing in new perspectives, voices, ideas for effective strategies, and nuanced information on how risks are inequitably distributed (Corburn 2003).

Planners can work closely with community-based organizations to develop heat strategies and plans collaboratively with community members, even if this takes additional time. As an example, the Nature's Cooling Systems project in Phoenix worked with community

PLAN INTEGRATION FOR RESILIENCE SCORECARD FOR HEAT

The Plan Integration for Resilience Scorecard for Heat (PIRSH) is a tool being developed by this report's authors that communities can use to examine how different plans would affect heat risk and to identify inconsistencies across the network of plans. It provides a systematic process with the following steps:

1. Evaluating heat mitigation strategies across the network of plans
2. Mapping the spatial distribution of strategies and their combined effect across the community
3. Comparing those maps with heat risk data
4. Identifying opportunities to improve heat resilience planning

The PIRSH builds on the Plan Integration for Resilience Scorecard, which was originally developed in 2015 for understanding the integration of plan networks in the context of flooding hazards (Berke et al. 2015). Since then, a detailed guidebook (Malecha et al. 2019) and *PAS Memo* (DeAngelis et al. 2021) have been written on the methodology, and it has been applied in a number of communities across the United States and in the Netherlands (Berke et al. 2019; Yu, Brand, and Berke 2020; Woodruff et al. 2021). When researchers evaluated the outcomes of some of these applications, they found that the process helped participating communities learn the full extent of policies stemming from different departments, reconcile conflicts, and make changes to both specific policies and planning processes based on identified gaps (Berke et al. 2021).

The PIRSH guidebook (Figure 4.5) explains the methodology in detail, but generally, the first step in applying the PIRSH is for the project team to compile current community plans that are most relevant for the development of the built environment and heat mitigation strategies. Depending on the community, these might include comprehensive or general plans; climate action, climate change mitigation, or sustainability plans; hazard mitigation plans; parks and recreation plans; and transportation plans. Citywide and small area plans are also potentially relevant.

Second, the team should review the plans and identify all policies that have the potential to exacerbate or mitigate urban heat. To be included, a policy must pass a three-point test:

1. It must have the potential to affect vulnerability to heat.
2. It must refer to a mappable location or area.
3. It should contain a recognizable policy tool or an intervention to achieve specific objectives and outcomes.

Policies that meet these three criteria are entered into a spreadsheet and categorized based on the most relevant policy tool and the heat mitigation strategy or strategies.

Team members should then score the policies based on whether they would likely exacerbate (scored -1) or mitigate urban heat (scored +1). A score of 0 can be given if the impact is expected to be neutral. It may also be helpful for a community to include policies that would likely affect heat risk, but for which the information provided in the plan is insufficient to determine whether that impact would be positive or negative. These policies receive an "Unknown" score.

As an example, a policy calling for investments to develop a new bikeable and walkable green space along a particular road would be scored +1 because this capital improvement would reduce waste heat by reducing automobile use and mitigate heat through urban greening. Conversely, a policy calling for increased density of industrial land would be scored a -1 because this land-use change would likely exacerbate the UHI effect by increasing impervious surface and waste heat from industrial processes. A policy creating a new affordable housing development would be included because this land-use change would likely have an effect on heat, but the net effect is unknown based on the description.

The community should be divided up into districts, for example, census tracts, and policy scores assigned to each district where they apply. Scores can then be added up for each district and each plan to understand how different plans would mitigate or exacerbate heat across the community.

District scores can be mapped and layered with other spatial data on heat risk, such as land surface temperature maps or social vulnerability indices (see Chapter 2 for potential data sources), to identify gaps and where interventions are needed.

Figure 4.5. The PIRSH can help communities examine how different plans affect heat risk and identify inconsistencies across the network of plans (Ladd Keith and Sara Meerow)

leaders in several high-need neighborhoods to hold a series of three workshops to inform the development of heat action plans (Guardaro et al. 2020). This process helped to build community members' awareness that heat could be mitigated in their neighborhood, trust between the community and government officials, and a shared understanding of specific local needs. Local governments can also work with trusted local public health providers to reach vulnerable community members, as discussed in the sidebar in Chapter 6, p. 67 (Garfin, LeRoy, and Jones 2017).

IMPLEMENTATION AND MONITORING

To ensure that heat resilience strategies across a community's network of plans are integrated and ultimately implemented, all strategies should indicate who is responsible, a timeline for implementation, and potential funding sources.

Given how rapidly the science on urban heat is evolving, it would be beneficial for planners to monitor and evaluate how strategies work. Regularly assessing the metrics of success listed at the beginning of this chapter (e.g., heat illnesses, tree canopy cover) would help determine if the strategies are working and allow for any necessary adjustments.

Partnerships among planners and universities, nonprofit organizations, and federal programs could be helpful for this. For example, Phoenix is working with researchers at Arizona State University to monitor the performance of its new cool pavement pilot program (see the sidebar on p. 46). Some communities may already have existing partnerships with a university, nonprofit, or federal program, but for those communities that do not, Chapter 2 includes information on potential partners and data sources for heat planning.

CONCLUSION

Planners should consider seven practical principles for planning for heat resilience. First, communities need to set realistic goals for urban heat mitigation and management that are linked to measurable metrics for success. Metrics should be based on a sound understanding of current and future heat risks, which means combining climate and sociodemographic information. This should inform the development of a diverse portfolio of heat mitigation and management strategies that target the highest-risk areas and community members and are robust to future uncertainties.

Strategies must be planned, implemented, and monitored in collaboration with many different stakeholders, including various city departments, utilities, community-based organizations, nonprofits, the private sector, and marginalized communities. Strategies may be implemented in different community plans or outlined in a dedicated heat plan, but either way, some integration is needed.

Planners can use PIRSH as a methodology for assessing and improving plan integration for heat resilience. New York City and Phoenix provide many real-life examples of how cities can put heat planning resilience principles into practice.

The next two chapters delve deeper into the various strategies for heat mitigation (Chapter 5) and heat management (Chapter 6).

NEW YORK CITY: CROSS-CITY COLLABORATION TO REDUCE HEAT RISK

From 1970 to 2000, New York City averaged approximately two heat waves per year. But climate projections show that this number could increase to seven per year by 2050, and the number of days over 90°F (32.2°C) could triple from 18 to 57 (U.S. EPA 2021c). Due to the city's geography, these high temperatures can be made even more dangerous by high humidity levels, resulting in unsafe Heat Index temperatures as determined by the National Weather Service.

New York City is almost entirely built out, with a high proportion of older buildings at various levels of weatherization. In 2007, 87.5 percent of the city's eight million residents reported having air conditioning, meaning that hundreds of thousands of residents likely still do not (New York 2022b). Many of these residents have lower incomes and live in older buildings that lack weatherization and are prone to temperature extremes. In fact, temperatures in units without air conditioning can be up to 20°F (11°C) higher than outdoor temperatures (Charles-Guzman 2021). On average, 350 deaths are attributed to extreme heat each year in the city (New York 2022a).

To better understand which neighborhoods were most at risk and help reduce the impacts of heat on the city's residents, New York City developed a heat vulnerability index (HVI). The HVI identifies neighborhood vulnerability based on surface temperature, green space, access to home air conditioning, and the percentage of residents who are low-income or non-Latinx Black (NYC Department of Health 2022).

The HVI helped the city locate cooling centers, provide transportation to cooling centers, improve risk communication, and arrange for home check-ins for high-risk individuals. Informed by the HVI, the Cool It! NYC program helps to increase public awareness of existing public cooling features such spray showers, drinking fountains, and tree cover for shade during extreme heat events and aids in the development of new features (NYC Department of Parks & Recreation n.d.).

To mitigate heat in the built environment and reduce energy usage, New York City amended its building codes in 2011 to require "cool roofs," or the use of reflective or white coatings on rooftops. Codes were updated in 2019 (Local Law 92 and 94) to require green (vegetated) roofs or rooftop solar photovoltaics (The Urban Green Council and The Nature Conservancy 2019). The NYC °CoolRoofs program also has a jobs training and placement component, through which workforce participants learn to install cool roofs through paid training and experience for future construction careers (New York n.d.).

In 2017 the city launched the Cool Neighborhoods NYC plan (Figure 4.6) and a $106 million implementation program to better coordinate existing efforts to address heat and scale up heat mitigation and management. This included several new initiatives such as the Be-a-Buddy NYC (New York 2017) program to increase education about heat risk and encourage residents to check on their most vulnerable neighbors. As part of the Cool Neighborhoods NYC program, the city also committed $82 million to fund street tree planting in areas identified on the HVI map.

To reduce indoor cooling inequities during the COVID-19 pandemic, the city distributed 74,000 air conditioners to low-income seniors (Culliton 2020). The program assisted many more residents than had previously received benefits under the federally funded Home Energy Assistance Program (HEAP). The city also worked with the New York State Public Service Commission to provide $70 million in aid to help up to 440,000 families pay for summer utility bills in 2020 (New York 2020).

The city's Climate Resiliency Design Guidelines (NYC Mayor's Office of Resiliency 2020) include several considerations for extreme heat. To help reduce the UHI effect, the design guidelines require a minimum of 50 percent of project site areas to be shaded, vegetated, or use reflective surfaces. Industrial sites must reduce waste heat by using waste heat recovery technology, electric charging technology, and improved HVAC controls. The guidelines also call for heat-resilient facilities that are designed using forward-looking climate data. This includes the identification of potential facility system failures due to heat stress and an evaluation of how the facility contributes to a resilient energy grid. Finally, the guidelines also call for occupant thermal safety through passive or mechanical indoor cooling (NYC Mayor's Office of Resiliency 2020).

With one of the largest city governance structures in the United States, the New York City's Mayor's Office of Climate Resiliency currently coordinates extreme heat efforts in partnership with other departments such as NYC Parks, Health Department, Small Business Services, and Emergency Management.

Cool Neighborhoods NYC
A Comprehensive Approach to Keep Communities Safe in Extreme Heat

The City of New York
Mayor Bill de Blasio

Anthony Shorris
First Deputy Mayor

#ONENYC

Figure 4.6. The Cool Neighborhoods NYC plan (City of New York)

PHOENIX: HEAT RESILIENCE EFFORTS IN ONE OF THE HOTTEST U.S. CITIES

The City of Phoenix has been one of the fastest growing cities in the United States for much of the past century, with a population growing from 106,818 in 1950 to 1.68 million in 2020. Phoenix is now the fifth-largest city in the country (U.S. Census Bureau 2020).

The city's historically low-density development has had implications for the region's urban heat island effect, with temperatures on the hottest days in urban areas being up to 15°F (8.3°C) hotter than surrounding natural areas. The desert Southwest is also one of the fastest-warming regions in the United States due to climate change (USGCRP 2018). The combination of rapid development and climate change have led to a 4.3°F (2.4°C) average temperature increase for Phoenix from 1970 to 2018, more than twice the average rate of increase across the contiguous United States (Climate Central 2019).

The extreme heat in Phoenix has real consequences for human health and well-being. Heat-associated deaths in the metropolitan area increased from 199 in 2019 to 323 in 2020, a 62.3 percent increase (Maricopa County Department of Public Health 2021).

The City of Phoenix has long recognized the threat of extreme heat and has implemented several heat mitigation and management strategies. The city's zoning ordinance (§1207) requires shade standards for the downtown area: a minimum of 75 percent of sidewalks and a minimum of 50 percent of public spaces must be shaded, as measured by summer solstice at noon (Phoenix 2022). In 2010, the city adopted a Tree and Shade Master Plan, which aims to increase tree canopy cover to 25 percent, an aggressive goal given the city's total estimated cover for all vegetation is 13 percent (Phoenix 2010).

In 2020, the city partnered with Arizona State University to evaluate a cool pavement treatment to reduce the heat trapped by roadway infrastructure and now has more miles of cool pavement treatment than any other U.S. city (Figure 4.7) (Phoenix 2021a). Preliminary results show that the cool pavement reduced temperatures up to 12°F (6.7°C) compared to the traditional pavement, but also increased heat exposure of pedestrians by 5.5°F (3.1°C) from noon through the afternoon (Phoenix 2021a).

In addition to heat mitigation, the city has been partnering with the county and state health departments and regional government on heat management strategies. One such effort is the Heat Relief Network, formed in 2005 after a heat wave led to the deaths of 30 people who were experiencing homelessness. The Heat Relief Network is led by the Maricopa Association of Governments and coordinates extreme heat event efforts with local governments, nonprofits, faith-based communities, and businesses. It produces an up-to-date map of cooling centers, hydration stations, and donation collection sites for water and toiletries (MAG n.d.). The city also helps reduce heat-related illnesses and deaths of residents and tourists in the city's desert and mountain park trails through informational signage and trail restrictions during extreme heat periods.

To help coordinate these ongoing efforts, which are spread across departments and levels of government, the City of Phoenix created its Office of Heat Response and Mitigation in 2021. This was the first publicly funded office of its kind in the United States. The office is tasked with creating a strategic action plan to help coordinate ongoing and new activities to address extreme heat and will also house both built environment and urban forestry specialists to help mitigate urban heat (Phoenix 2021b).

Figure 4.7. Workers applying a cool surface coating to streets in the City of Phoenix as part of a pilot project being evaluated by Arizona State University (City of Phoenix)

CHAPTER 5

HEAT MITIGATION STRATEGIES

Heat mitigation strategies aim to cool cities, neighborhoods, and heat-vulnerable locations by reducing contributions from the built environment and waste heat to the urban heat island (UHI) effect. These strategies include land-use planning, urban design, urban greening, and waste heat reduction. The sidebar on p. 49 shows how these strategies can be integrated into a community to mitigate heat.

While many of these strategies are already considered by urban planners for other purposes, their heat mitigation benefits are often less commonly known or highlighted. Planners should incorporate and highlight the heat mitigation benefits of relevant strategies in their community's land-use regulations, long-range plans, and capital improvement programs to help ensure their community is developed with heat resilience in mind.

Other professions with a role to play in heat mitigation include hazard mitigation planning, architecture, landscape architecture, civil engineering, and real estate development. As discussed in previous chapters, heat mitigation strategies should be developed through equitable public participation and targeted to the most heat-vulnerable areas. Heat mitigation strategies should also maximize co-benefits, weigh trade-offs, and avoid maladaptation when possible.

This chapter defines four main categories of heat mitigation strategies and the specific strategies that fall within each of them, explains how they can help to cool communities, and provides examples of where they have been implemented.

LAND-USE PLANNING

Land-use planning is a critical component of effective heat mitigation, as the built environment affects local climates. Similar to other climate risks, where and how communities develop determine their exposure to heat risks.

Large-scale land-use considerations at the city and regional levels include overall urban development patterns, conservation of natural areas, and ventilation corridors to maximize cooling benefits. The minimization or reduction of heat-trapping surfaces associated with the transportation system, such as roadways and parking lots, can also help decrease the UHI effect. Conversely, expanding urban development, as shown in Figure 5.1, can exacerbate urban heat. Planners can play a critical role in increasing urban heat resilience by incorporating heat mitigation strategies into their land-use planning practices.

Urban Development Patterns

Urban development patterns can be defined as the organization of an urban area's growth, which leads to the large-scale form of the built environment (Farzaneh, Daryani, and Mokhberkia 2019). They comprise the history of a city's land-use decisions, both at the site level and through longer-range planning activities such as growth management.

Whether the urban development pattern is dense and compact, whether there is a central downtown or sprawling suburbs, and whether rural and natural areas have been preserved—all these characteristics affect the severity and

Figure 5.1. Extensive development in Southwestern cities such as Las Vegas has increased their UHI effect (Wasif Malik/Flickr (CC BY 2.0))

ENVISIONING A COMMUNITY WHERE URBAN HEAT IS MITIGATED

What would a community that proactively mitigates heat look like? Figure 5.2 combines the different heat mitigation strategies discussed throughout this chapter to visualize how they could come together. With respect to land use, open spaces have been conserved and surface parking is minimized. Buildings are oriented to maximize shade and increase ventilation and designed to maximize shade for pedestrians and energy efficiency. A variety of shade structures shelter pedestrians, park users, and those waiting at transit stops. Cool pavements are used on the road and different forms of urban vegetation and water features are incorporated into site design. The community further reduces waste heat by promoting walking, bicycling, and public transportation.

Figure 5.2. Heat mitigation strategies within a community (Ladd Keith and Sara Meerow)

spatial distribution of heat risks. Shifting the urban development pattern is a long-range planning activity, but it can have a significant impact on the UHI effect.

Any expansion or growth of an urban area will likely increase the UHI effect if heat mitigation strategies are not applied. For example, a study of 53 U.S. metropolitan regions found that the rate of increase of extreme heat events was higher in regions with sprawling urban development patterns versus compact urban development patterns (Stone, Hess, and Frumkin 2010). Compact development patterns can also increase the UHI effect, but the use of vegetation, cool surfaces, and other heat mitigation strategies at the urban design level can help mitigate these increases (Kamruzzaman, Deilami, and Yigitcanlar 2018; Saleem et al. 2020).

Roadways and Parking Lots

The use of manmade materials such as asphalt and concrete for parking lots and roadways is one of the main, if not the largest, contributors to the UHI effect (Mohajerani, Bakaric, and Jeffrey-Bailey 2017).

Asphalt and concrete have low albedos and high heat absorption capacities, meaning that solar radiation is mainly absorbed and reemitted as heat (Mohajerani, Bakaric, and Jeffrey-Bailey 2017). Planners can mitigate the heat contributions from roadways and parking lots by reducing

ELIMINATING PARKING REQUIREMENTS IN MINNEAPOLIS

The City of Minneapolis is making strides towards its goal of an 80 percent reduction in greenhouse gas emissions by 2050, as outlined in the Minneapolis 2040 Comprehensive Plan, which encourages alternative modes of transportation (Figure 5.3). In May 2021, the city council voted 13–0 to no longer require new developments to accommodate minimum parking requirements and to incrementally lower maximum parking allowances (Minneapolis 2021).

City Council President Lisa Bender explained that this does not restrict developers from adding parking to new projects; instead, it gives more flexibility to urban development (Jackson 2021). The ordinance is intended to increase the use of more sustainable modes of transportation, such as walking, bicycling, and transit. Along with decreasing vehicle parking requirements, it increases bicycle parking requirements and adds new travel demand management strategy requirements to every residential building with 50 or more units (Jackson 2021).

While this ordinance was not passed with urban heat resilience in mind, it does provide several heat mitigation benefits. First, parking lots are a major contributor to the UHI effect, and there is ample evidence that most U.S. cities require more parking than is needed. Reduced parking lot requirements for new development will help mitigate future UHI effect increases. The potential redevelopment of existing parking lots into other land uses can also help decrease the UHI effect. The ordinance also encourages alternative modes of transportation, which reduce greenhouse gas emissions that contribute to climate change and reduce waste heat, another contributor to the UHI effect.

Figure 5.3. An Open Streets event in Minneapolis connecting several parks along three miles of streets to transform city corridors into car-free places (Our Streets Minneapolis)

Figure 5.4. The Skysong Center in Scottsdale, Arizona, features dramatic shade structures, drought- and heat-tolerant vegetation, and building orientation for heat mitigation (Cygnusloop99/Wikimedia Commons (CC BY-SA 3.0))

or eliminating parking lot requirements, implementing road lane reductions, and planning for complete streets.

Many communities are considering reducing or even moving towards eliminating parking requirements, but the heat mitigation benefits are not often weighed along with other considerations. Research has shown that the availability of parking largely determines auto usage, so not only does lessening the size and quantity of parking lots benefit the UHI effect by reducing materials with high heat capacity, it can also reduce vehicle usage (Weinberger 2012). The sidebar on this page discusses the experience of Minneapolis in eliminating parking requirements. Parking lots can also be required to provide a certain amount of shading through either trees or built shade structures and to be broken up by vegetation and natural surfaces to decrease heat impacts.

Road lane reductions, or narrowing roads and using the right-of-way for sidewalks, bicycle lanes, or vegetated space, can also be used to mitigate the UHI effect and encourage alternate modes of transportation (Tan 2011). New streets can similarly be designed as complete streets, focusing on alternative modes of transportation and incorporating shade for pedestrians. For the roads and parking lots that remain, "cool" pavement coatings can be applied, as discussed later in this chapter.

Ventilation Corridors

Ventilation corridors are air passages in an urban area that decrease the UHI effect and improve human thermal comfort (Xu et al. 2021). Ventilation corridors function by increasing airflow and removing and replacing stagnant hot air with fresh, cooler air (Du, Zhu, and Fang 2017; Hsieh and Huang 2016).

These air passages can be built on regional, urban, district, and neighborhood scales, and can be integrated at the site level to improve microclimates (Ren et al. 2018). For instance, on a regional scale, natural landscape features within an urban area, such as hills, valleys, or open space for water, can function as large-scale ventilation corridors. On a district or neighborhood scale, the arrangements of buildings within a block can be optimized to allow air passages that increase airflow through the built environment. At the site scale, buildings may be configured to have more ventilation passages and open spaces that allow greater airflow and discourage stagnant hot air from collecting (Figure 5.4, p. 50).

In urban areas, newly identified ventilation corridors can be redesigned to enhance the airflow of existing features such as rivers, wider streets, and areas with low-rise buildings (Gu et al. 2020). Vegetation within ventilation corridors can help more effectively lower nighttime air temperatures, even in areas with lower wind speeds (Eldesoky, Colaninno, and Morello 2020). Ventilation corridors can also be planned ahead as part of the design process for new development to ensure that existing airflow is not blocked by new buildings.

Ventilation corridors are impacted by local climatic contexts, such as seasonal changes in atmospheric circulation, or where airflow patterns shift throughout the year. This makes an understanding of regional climatic conditions essential in their planning and design (Xu et al. 2021). Ventilation corridors are a particularly relevant strategy for large and dense coastal cities, such as New York, Tokyo, and Hong Kong, where multiple blocks of high-story buildings can inhibit airflow, trapping heat and air pollutants.

Figure 5.5. A shade structure designed and built by architecture students at the University of Arizona uses ventilation for increased air flow to help keep students and faculty cool (University of Arizona, CAPLA)

Land Conservation

The UHI effect is increasing in communities across the country due to continued growth and development. Large-scale land conservation—protecting natural land or returning developed land to its natural shape (Wiens 2009)—can help reduce future exacerbation of the UHI effect.

While land conservation is not often considered a heat mitigation strategy, it preserves the cooling effects from more rural, agricultural, or natural areas. Several cities, including Portland, Oregon; Boulder, Colorado; and Honolulu, Hawaii, have established urban growth boundaries to manage land conservation. Other cities, such as Tucson in Pima County, Arizona, have opted to create a conservation lands system to guide development based on the ecological importance of natural areas. Planners should consider the heat mitigation benefits of land conservation as part of their long-range and growth management planning.

URBAN DESIGN

Site-level urban design affects both larger-scale UHI effects as well as microclimate, including human thermal comfort on the site.

Urban design is often regulated through zoning and land-use regulations, streetscape guidelines, and urban design guidelines. Urban design strategies for heat mitigation include orienting buildings and streets for shade, adding shade structures (Figure 5.5), and using cool pavements, walls, and roofs.

Street and Building Orientation

The orientation of streets and buildings affects microclimate and human thermal comfort. While both street and building orientation are often already predetermined in many communities, awareness of solar angles can help planners and designers better position buildings to increase shade for pedestrians. Both street and building orientation is context specific and should involve knowledgeable design professionals to consider local solar exposure and wind patterns throughout the year (Aleksandrowicz et al. 2017; Van Esch, De Bruin-Hordijk, and Duijvestein 2007).

Generally, streets that are oriented north/south (those that run from north to south) are cooler than those oriented east/west (those that run from east to west). This is because north/south-oriented streets are shaded during the morning and afternoon, while the east/west-oriented streets have sun exposure all day (Jamei et al. 2020). Street orientation is also essential as it frequently becomes the default for how buildings are oriented. While many U.S. communities already develop on a predetermined street grid, there may be opportunities to consider street orientation in new greenfield development. Keeping the street orientation in mind for solar angles can also help planners determine sidewalk locations unshaded by buildings that would benefit from additional tree canopy or built shade structures.

Buildings that are oriented with local climate and geographic conditions in mind can similarly help improve

Figure 5.6. The diversity of shade options includes shade sails (top left and right), built shade structures (bottom left), and vegetation and tree canopy (bottom right) (Maricopa Association of Governments)

REVITALIZING DOWNTOWN TUCSON WITH SHADE

The City of Tucson incorporated shade and heat mitigation considerations into its continued efforts to revitalize its downtown. The Infill Incentive District (IID) is a form-based overlay zone for the downtown and surrounding neighborhoods created in 2013 and updated in 2015 to provide an alternative to the original zoning (Tucson 2022). The IID incentivizes historically and environmentally appropriate development and offers reduced parking requirements and increased density. Different subdistricts preserve diverse neighborhood characteristics.

The IID requires heat mitigation and shade both in building and streetscape design. For the core downtown area, the IID requires shade to be provided for at least 50 percent of all sidewalks and pedestrian pathways as measured at 2:00 p.m. on June 21 when the sun is 82° above the horizon as based on 32°N latitude (UDC §5.12.7). This shade may be accomplished through building mass, shade structures, canopies, arcades, or trees. Deciduous trees are encouraged as an alternative to evergreen trees.

New buildings must also have a maximum of 50 percent glass on east and west exposures, complemented by minimum shade of 50 percent as calculated between 10 a.m. and 3 p.m. between May and October, the region's hottest period, to reduce heat gain (UDC §5.12.7). North and south exposures have no glass or shade requirements.

The incorporation of shade as a requirement (Figure 5.7), with flexible options for developers to meet it based on site conditions, ensures that new development in downtown Tucson will contribute to the city's urban heat resilience.

Balconies provide shade and shadows on this residential building.

Balconies in the shade provide special spaces.

A fabric canopy serves as a stylized design element for this restaurant.

Suspended metal canopies create an interesting architectural detail.

Trellis and umbrellas provide shade and shadows.

Figure 5.7. Tucson's Downtown Urban Design Reference Manual recommends a variety of creative shade solutions to create continuous and visually appealing shaded spaces throughout the downtown area (City of Tucson)

natural ventilation, avoid solar heat gain, decrease energy usage, and improve human thermal comfort (Bekkouche et al. 2013; Rad and Afzali 2021; Iyendo et al. 2016; Nayak and Prajapati 2006). For example, a taller building sited in proximity to a north/south-oriented road can help provide effective shade for pedestrians, as the building would block the sun for part of the day. Buildings can also be oriented to take advantage of naturally prevailing wind directions to create small ventilation corridors that improve natural ventilation on the site. Building orientation influences which sides of the buildings have the most solar exposure, affecting energy efficiency and waste heat considerations. On building sides with high solar exposure, improvements such as shade screens, window glazing, and smaller windows on the east and west sides can help shade and keep the inside of buildings cooler.

In urban areas where the orientation of streets and buildings is already determined, planners can prioritize other heat mitigation measures (e.g., greening, construction of shade structures). These will be most effective when designed with an understanding of how solar exposure affects the built environment and community members, both indoors and outside, throughout the year.

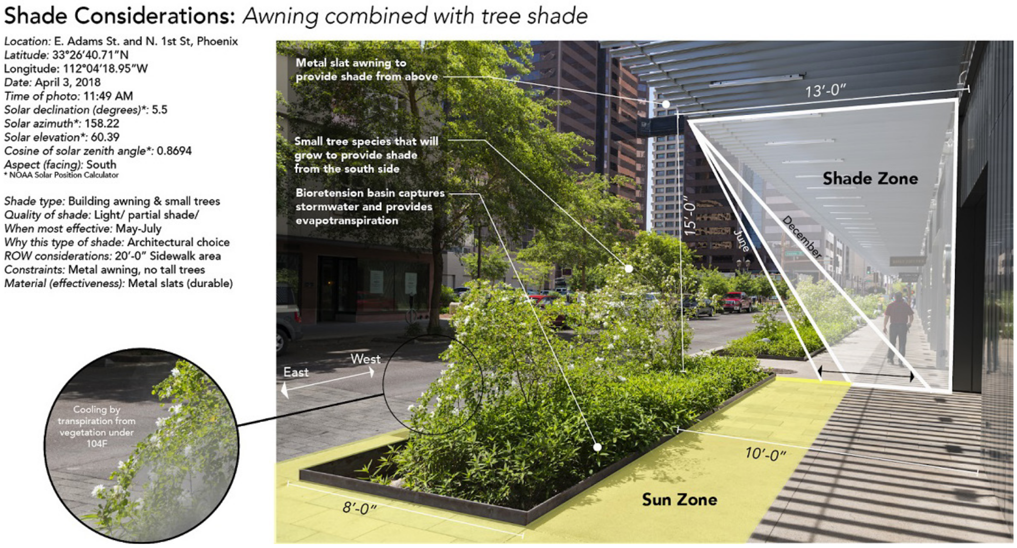
Building Shape and Massing

The specific arrangements of buildings, infrastructure, and open spaces on a site also shape the microclimate (Krüger, Minella, and Rasia 2011). Building shape and massing designed for heat mitigation can improve human thermal comfort, decrease energy usage, and improve airflow (ESMAP 2020).

Building shape determines how much of the building will be exposed to solar radiation (Roslan and Ismail 2018). Buildings with less wall and roof area exposed to the sun will stay cooler, as they will not absorb as much solar radiation (Wonorahardjo et al. 2020). The ratio of building height to street width is an indicator of how much sunlight and radiation reaches the street and heats the air near the ground. Building height can cause the microclimate to change within cities by changing wind movement patterns (Li and Donn 2017).

In many locations, traditional architectural styles used before the advent of air conditioning present lessons that can be reincorporated into building practices. For example, Mediterranean and Latin American-style courtyard designs maximize a building's thermal mass and shade inside the courtyard to improve human thermal comfort (Burgess and Foster 2019). In addition, purposefully designing buildings to shade surrounding pedestrian areas may be a helpful heat mitigation strategy, as the shade from buildings can be more extensive and consistent, and therefore have a greater cooling effect, than trees or built shade structures.

In humid climates, leaving space between buildings can be beneficial from a heat perspective because it facilitates the flow of air, while in more arid locations, it may be more beneficial to place buildings closer together where they can shade each other.



Shade Considerations: *Awning combined with tree shade*

Location: E. Adams St. and N. 1st St, Phoenix
Latitude: 33°26′40.71″N
Longitude: 112°04′18.95″W
Date: April 3, 2018
Time of photo: 11:49 AM
Solar declination (degrees):* 5.5
Solar azimuth:* 158.22
Solar elevation:* 60.39
Cosine of solar zenith angle:* 0.8694
Aspect (facing): South
* NOAA Solar Position Calculator

Shade type: Building awning & small trees
Quality of shade: Light/ partial shade/
When most effective: May-July
Why this type of shade: Architectural choice
ROW considerations: 20′-0″ Sidewalk area
Constraints: Metal awning, no tall trees
Material (effectiveness): Metal slats (durable)

Figure 5.8. Pedestrian shade can be maximized by using both streetscape vegetation and built shade structures attached as architectural features (Paul Coseo & Maricopa Association of Governments)

Figure 5.9. The Rose Kennedy Greenway in Boston, where an elevated highway was moved underground to allow for a connected greenspace in the urban core (Greenway Conservancy (CC BY-SA 4.0))

Shade Structures

Provision of shade is a critical component of heat mitigation, and it can be increased with strategically placed trees, buildings, and built shade structures (Figure 5.6, p. 52) (Jamei et al. 2020).

Not all shade is equal. One study found that shade from buildings was most effective at reducing surface and mean radiant temperatures, followed by trees and lightweight built shade structures such as canopies (Middel et al. 2021). The effectiveness of building shade depended on the orientation of the sun, and that of tree shade depended on the species of tree and canopy type. As recommended by the study, planners should implement the “right shade in the right place” (Middel et al. 2021).

Built shade structures, such as ramadas, pergolas, arbors, and canvas shades, improve human thermal comfort and increase the walkability of an area (Bande et al. 2015). Built shade structures are a more immediate heat mitigation strategy than trees, which take time to mature.

Built shade structures attached as architecture features can also decrease a building’s exposure to heat, reducing energy requirements and related waste heat (Shashua-Bar, Pearlmutter, and Erell 2011). Fixed overhangs are very effective at shading south-facing windows in the summer when sun angles are high. However, the same horizontal device is ineffective at blocking low afternoon sun from entering west-facing windows during peak heat gain periods in the summer (Datta and Chaudhri 1964). This suggests that multiple layers of sun protection may be needed (e.g., blinds in addition to external overhangs).

Planners can also integrate minimum shade requirements along streets and buildings through streetscape and urban design guidelines (Figure 5.8, p. 54). As described in the sidebar on p. 53, the City of Tucson is incorporating shade requirements into its downtown revitalization plans.

Cool Pavements

Cool pavements include both lighter-colored pavement coatings, which reflect more of the sun’s radiation, and evaporative pavement technologies, which are permeable to water and cool the environment as that water evaporates. Cool pavement coatings are suitable for hot and semi-arid regions, while evaporative pavements are suitable for areas with more water availability (Qin 2015).

Cool pavements can directly decrease the UHI effect and have benefits for building energy usage (Synnefa, Santamouris, and Livada 2006), which in turn reduces waste heat and greenhouse gas emissions. Cool pavements store less heat than traditional pavements, resulting in lower surface temperatures during the day and less heat released during the night (U.S. EPA 2008b). Cool pavement coatings may also increase the life span of pavement (Pomerantz, Akbari, and Harvey 2000). Evaporative pavements have additional benefits, such as reducing urban flooding, improving water quality, and increasing vegetation when vegetated pavers are used (Qin 2015).

However, cool pavements can take a longer time to install and add extra costs, and uncertainties remain regarding their long-term effectiveness (Georgakis, Zoras, and Santamouris 2014). In addition, pavement coatings that are very light can reflect solar radiation back at pedestrians or nearby buildings, thereby reducing human thermal comfort for those walking on the pavement and increasing building energy use (Middel et al. 2020). Research quantifying these tradeoffs in cities like Phoenix is ongoing (see sidebar in Chapter 4, p. 46).

URBAN GREENING

Urban greening strategies such as urban forestry, green stormwater infrastructure, green roofs, parks, and greenways can help mitigate the UHI effect and cool microclimates.

A COOL CORRIDOR FOR LAS CRUCES

Like many cities in the U.S. Southwest, Las Cruces, New Mexico, is facing increasing temperatures due to growth and associated UHI effect and climate change. This city of 104,672 has grown 40 percent since 2000 and now has an average of 120 days a year with highs of 90° F (32° C) or warmer.

With growing concerns about extreme heat, the city partnered with the NASA DEVELOP program to create a UHI map based on satellite land surface temperatures. The information about areas with the highest land surface temperatures, along with census data of the location of minority and low-income residents, helped Las Cruces identify a location for a pilot “cool corridor” (NASA 2020).

A cool corridor is a street targeted for several heat mitigation strategies to both reduce the UHI effect as well as improve human thermal comfort. The city selected Nevada Avenue, a small but important route through several low- to moderate-income neighborhoods. The cool corridor improvements featured chicanes (a series of alternating midblock curb extensions) to slow traffic, decrease existing asphalt, and increase vegetation (Figure 5.10).

Las Cruces’ semi-arid environment makes water conservation a top consideration, so green stormwater infrastructure was used to direct rainwater to new vegetation. The vegetation and trees selected were all native to the Chihuahuan Desert. The $250,000 project was installed in 2018 and funded through the city’s sustainability office, stormwater management department, and a community development block grant.

Figure 5.10. View of Nevada Avenue in Las Cruces, New Mexico, with proposed changes to create a cool corridor (City of Las Cruces)

Urban greening is the network of planned and unplanned green spaces within an urban area (Figure 5.9), spanning both the public and private realms and managed as an integrated system (Lovell and Taylor 2013). A holistic system of vegetated parks and open spaces is an essential heat mitigation strategy because of the multiple benefits urban greening provides to the community and local ecosystems (Norton et al. 2015). Vegetation cools surrounding areas through evapotranspiration and trees provide shade when strategically placed (Meerow, Natarajan, and Krantz 2021). These strategies also have the co-benefits of reducing urban flood risk, creating ecological habitat, and providing psychological benefits to community members (Meerow 2020).

Though urban greening strategies are the most common heat mitigation strategies used across the United States, according to a survey of planners (Meerow and Keith 2021), factors such as maintenance cost should be considered in their implementation. The increase in water use needed to maintain vegetation is also a trade-off that arid and semi-arid cities with scarce water resources should be aware of (Shashua-Bar, Pearlmutter, and Erell 2011).

The design, implementation, and maintenance of urban greening should also close the environmental justice gap (Talen 2010). This means that new parks and open spaces should be strategically planned in neighborhoods that lack them but also carefully designed with those communities to avoid “green gentrification” (Hoover et al. 2021; Wolch, Byrne, and Newell 2014). The Barcelona Laboratory for Urban Environmental Justice and Sustainability has developed a toolkit for developing just urban greening policies and programs (Oscilowicz et al. 2021).

Planners can play a key role in helping to coordinate their community’s urban greening strategies in partnership with landscape architects, parks and recreational departments, public works departments, and arborists. Planners should also engage community members in urban greening, particularly in historically disinvested communities, to ensure that the benefits are known and the urban greening selected is appropriate for the community.

Urban Forestry

Many U.S. cities are pursuing tree-planting campaigns to grow their urban forests, planting trees individually or in groups to increase tree canopy (Schwarz et al. 2015). Increasing urban forestry can decrease the UHI effect by

TEXAS MEDICAL CENTER'S DISTRICT ENERGY SYSTEM

An example of an effective waste heat reduction strategy is the Thermal Energy Corporation (TECO) district energy system at the Texas Medical Center (TMC) in Houston, which supports 200,000 people and houses sensitive medical materials (Figure 5.11).

TECO manages the district energy system, which at 36 miles of pipe is the largest district energy system in North America (Galehouse 2019). The system directs chilled water and steam through a series of pipes from an underground power plant. Chilled water is used for space cooling, cold rooms, and refrigeration, while steam is used to meet space heating, dehumidification, humidification, sterilization, kitchen, sanitary, and research requirements (TECO n.d.).

The system recycles waste heat and electricity, which reduces more than 32,500 tons of carbon emissions per year. In addition to its sustainability co-benefits, the heat-and-power-based system is a cost-effective way to control the temperatures throughout the large medical campus. This system has provided the TMC with thermally comfortable indoor spaces as well as decreased the waste heat contribution to Houston's UHI effect.

Figure 5.11. The Thermal Energy Corporation (TECO) district energy system (Texas Medical Center)

3.6–5.4°F (2–3°C) on average (Jamei et al. 2020), although the number of trees needed for noticeable effects varies by geography and climate. As explained in Chapter 3, low-income and minority neighborhoods often have lower amounts of tree canopy, making urban forestry an important component of heat equity.

Studies have found that trees are useful for midafternoon shade (Middel, Chhetri, and Quay 2015) and that the combination of trees and other vegetation can increase human thermal comfort (Shashua-Bar, Pearlmutter, and Erell 2011). Careful consideration of the layout and spacing of new trees is required for optimal cooling benefits (Middel, Chhetri, and Quay 2015). Deciduous trees that lose their leaves in the winter can provide shade in summer while allowing sun exposure during colder months of the year.

Additional water consumption, time to maturity, and the cost of planting and maintaining trees are important factors. For example, water consumption for outdoor landscaping in Phoenix accounts for roughly 45 to 70 percent of total residential water use (Declet-Barreto et al. 2013). This can be decreased by selecting native and drought-tolerant tree species and using green stormwater infrastructure (e.g., bioswales, curb cuts, and rainwater harvesting gardens) to help supplement watering needs.

Large-scale tree planning requires complex coordination. Trees also require considerable maintenance, and many planted trees never reach maturity (Pincetl et al. 2013; Roman et al. 2020). Urban forestry, while potentially effective for heat mitigation, is therefore not a panacea.

Vegetated Parks and Open Space

Vegetated parks and open spaces increase outdoor human thermal comfort and decrease the risk of heat-related illness (Chang, Li, and Chang 2007) as well as improve air quality (Oliveira, Andrade, and Vaz 2011). Residents living near parks and open spaces have been found to have less psychological distress, be more active socially, and have longer life spans (Cole et al. 2019).

Park and open space characteristics play an important role in cooling outcomes, however. Large parks (greater than 12 hectares/30 acres) are consistently much cooler than their surroundings, while small and medium-sized parks (3–12 hectares/7.4–30 acres) are only slightly cooler than most surrounding measurements (Chang, Li, and Chang 2007). As noted above, one issue with large-scale vegetated parks and open spaces is their use of water resources, especially in water-stressed regions (Shashua-Bar, Pearlmutter, and Erell 2011).

Green Stormwater Infrastructure

The Clean Water Act defines green infrastructure as "the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspiration stormwater and reduce flows to sewer systems or to surface waters" (U.S. EPA 2021e). Green stormwater infrastructure (Figure 5.12) helps to reduce the UHI effect, reduce urban flooding, and improve water and air quality (Matsler et al. 2021).

Green stormwater infrastructure must be designed for regional geographic and climate contexts. For example, in tropical areas, green roofs are not a valuable option for green stormwater infrastructure due to the higher concentrations in sediment and nutrient concentrations from the runoff compared to traditional roofs. In arid and semi-arid climates, green stormwater infrastructure can be valuable for harvesting scarce rainwater but may support less vegetation. Green stormwater infrastructure installed within streetscapes can help increase pedestrian thermal comfort through evapotranspiration.

Green Roofs and Walls

Green roofs and walls can help cool both the insides and outsides of buildings (Beecham et al. 2018). Green roofs can mitigate the UHI effect by decreasing heat-absorbing surfaces and can be used at the neighborhood scale for cooling purposes (Norton et al. 2015). Adding green roofs on lower buildings can improve outdoor human thermal comfort at the pedestrian level (Williams, Rayner, and Raynor 2010). Green roofs can also provide space for social interactions and can help reduce stress and anxiety (Nutsford, Pearson, and Kingham 2013). In narrow urban canyons created by the form and arrangement of buildings, green walls and facades with ground-level vegetation can helpfully increase ventilation and cooling effects at night (Norton et al. 2015).

Green roofs can be either *extensive*, meaning simpler systems with a depth of two to four inches, or *intensive*, meaning more complex systems that are often accessible for human use. The former require less structural support, while the latter require more structural support as they weigh much more (U.S. EPA 2021d). Green walls, also known as living walls or vertical gardens, can include trellises to allow plants to grow upwards and soil systems and irrigation at multiple levels. The complexity, costs, and benefits of green roofs and walls can vary substantially (Teotónio, Silva, and Cruz 2021).

Figure 5.12. Green stormwater infrastructure installed as part of Philadelphia's Green City Clean Waters, Green Street Program (Philadelphia Water Department)

Green roofs are best suited for non-arid climates where vegetation grows easily and for buildings that can structurally support the additional weight of soil and vegetation (ESMAP 2020). For example, green roofs and walls perform well in temperate or maritime climates but poorly in arid and semi-arid climates. Another consideration is that green roofs have higher installation and maintenance expenses than traditional roofing options (Susca, Gaffin, and Dell'Osso 2011).

Water Features

Water features mitigate heat through the use of water. Examples include natural or constructed bodies of water within urban areas (Gunawardena, Wells, and Kershaw 2017), fountains, splashpads, and mechanical misting systems.

Natural water features such as rivers, lakes, ponds, and streams can help mitigate the UHI effect, especially if they also support surrounding natural vegetation. Water features can act as a thermal buffer because water has a large capacity to absorb heat and can therefore cool the surrounding area (Oke 1988). Built water elements, such as pools, ponds, rills, artificial waterfalls, and streams, in landscape planning and environmental design can help decrease the UHI effect (Martins et al. 2016). Water features can also enhance human health and well-being, as people can use them to cool down in a heat event (Völker and Kistemann 2011).

The effectiveness of water features for heat mitigation depends on their local context; they are typically less effective in areas of high humidity versus areas with lower humidity levels. Water feature size is important, as larger bodies of water create more of a substantial cooling effect than smaller bodies of water (Sun and Chen 2012). Despite this, smaller water features in public spaces and parks such as fountains, misting features, and splashpads can cool the immediate area's microclimate, increasing human thermal comfort. Mechanical misting systems, such as those on outdoor patios or walkways, can also increase thermal comfort depending on design and operation (Oh et al. 2020). The use of water resources for heat mitigation must be weighed against water conservation goals, particularly for cities in semi-arid and arid climates.

Figure 5.13. The National Renewable Energy Lab's research facility building features a transpired solar collector, or dark colored metal sheeting on the south side of the building that collects heat from the sun, on the building exterior as well as solar shading over the windows (NREL)

WASTE HEAT REDUCTION

Waste heat generated by the mechanical processes in urban areas is a significant but often less-considered contributor to the UHI effect. Increasing building energy efficiency through weatherization and cool building surfaces can reduce the waste heat generated by indoor cooling and other mechanical systems. Decreasing vehicle use through the planning of transit and active transportation modes also decreases waste heat. These strategies also have the co-benefit of reducing local greenhouse gas emissions.

Waste heat can also be recovered in district energy systems, which decreases energy consumption (Jouhara et al. 2018). District energy systems are most commonly found in large universities and medical campuses in the United States but can be seen globally in cities such as London, Tokyo, Reykjavik, and Seoul (ESMAP 2020). One U.S. example from Texas is described in the sidebar on p. 57.

Building Energy Efficiency

Improving building energy efficiency can reduce waste heat emitted by building mechanical processes and reduce energy consumption. Weatherization programs and efficient lighting and heating, ventilation, and air conditioning (HVAC) systems help decrease building waste heat. Exterior building features such as solar collectors or solar shading can reduce building energy needs (Figure 5.13). Besides reducing a building's contribution to the UHI effect, energy efficiency has the added benefit of reducing greenhouse gas emissions.

Weatherization assistance programs incentivize more insulated and efficient residential and commercial buildings. Older and less-maintained buildings benefit the most from weatherization through the addition of increased insulation and more efficient windows and doors. Weatherization assistance programs have an important equity component as they can improve indoor human thermal comfort and reduce energy costs for residents who can least afford to pay high energy bills for indoor cooling, yet often live in inefficient homes.

Efficient HVAC systems, which move air between indoor and outdoor areas in commercial and residential buildings, can reduce waste heat, regulate indoor temperatures, and reduce energy use (Seyam 2018; ESMAP 2020). Heat pumps are energy-efficient alternatives to traditional furnaces and air conditioning that move hot or cold air from the air, water, or ground outside of a building to the inside of a building (Energy.gov n.d.). Efficient lighting, such as LED lights, can be up to 90 percent more efficient than traditional lights and emit less waste heat, requiring less related indoor cooling (EnergyStar n.d.). Optimizing the use of natural light within buildings can also help reduce artificial lighting needs.

Cool Roofs and Walls

Cool roofs and walls use light-colored materials that increase solar reflectance to reduce heat absorbed during the day and released at night. Both cool roofs and walls can reduce the UHI effect and decrease energy usage (Levinson et al. 2019).

Cool walls are exterior walls with higher albedo (reflectance) to help keep the inside of buildings cooler, cool the external microclimate, and mitigate the UHI effect (Levinson et al. 2019). Cool walls lower annual heating, ventilation, and air conditioning energy use and create more cooling during the night compared to cool roofs (Levinson et al. 2019), but they are not as effective in cooler climates (ESMAP 2020) and tropical climates (Li and Norford 2016). There is evidence that cool walls also perform better in less dense urban areas and may increase the energy use of buildings in denser urban areas (Nazarian et al. 2019). For example, if buildings with cool walls are close together, there is the potential for the heat energy to be reflected back and forth versus being dispersed (Nazarian et al. 2019).

Cool roofs can be installed during initial construction, or a coating can be applied to an existing roof at a relatively low cost. The life span of a cool roof is greater than that of a traditional roof because of reduced heat stress (Akbari and Matthews 2012). Cool roofs are more economical than green roofs (Klein, Crauderueff, and Carter 2008), and they are often more appropriate in arid and semi-arid environments where water is scarce. Cool roofs on taller buildings can reduce the overall UHI effect, though this strategy typically does not reduce temperatures at street level for human thermal comfort.

Vehicle Use Reduction

Waste heat from vehicles is an underestimated component of urban waste heat that increases the UHI effect. Reductions in vehicle waste heat mitigate the UHI effect, improve thermal comfort in microclimates, and improve air quality (ESMAP 2020).

Efforts to reduce vehicle use by enhancing alternative modes of transportation such as walking, bicycling, micromobility such as e-scooters, and transit can help reduce vehicle waste heat. Efficient and mixed land-use patterns can also lower vehicle waste heat by decreasing vehicle usage (Stone and Rodgers 2001). Electric vehicles can also help as they emit less waste heat than traditional combustion engines (Li et al. 2015).

Improving public transportation is another strategy to reduce vehicle waste heat. A study in Beijing found that the highest reduction of CO_2 emissions would result from replacing car travel with energy-efficient metro systems (Kolbe 2019) and that electric vehicles would be the second most effective approach to reducing GHG emissions, which in turn would reduce temperatures and waste heat.

CONCLUSION

Planners should pursue heat mitigation strategies to help reduce both chronic and acute heat risk in their communities. These strategies encompass land-use planning, urban design, urban greening, and waste heat reduction. Urban planners already consider many of these strategies, although often not explicitly, for their heat mitigation benefits. Planners can incorporate many of these heat mitigation strategies into their existing regulatory tools and planning processes, as discussed further in Chapter 7.

While heat mitigation strategies can help decrease the overall UHI effect, extreme heat events will still occur with increasing intensity, severity, and duration due to climate change. Many heat mitigation strategies are long-range in nature, meaning it will take time to shift the present form of the built environment to be more heat resilient. For this reason, it is imperative that communities also immediately employ heat management strategies, as discussed in the following chapter, to prepare for and respond to extreme heat events.

CHAPTER 6

HEAT MANAGEMENT STRATEGIES

Heat management strategies help communities prepare for and respond to chronic and acute heat risks. Even with effective heat mitigation efforts, climate change is still increasing average annual temperatures and leading to more frequent, longer-lasting, and more intense extreme heat events.

A primary heat management strategy is policies and programs that focus on resilient energy supplies and access to reliable and affordable indoor cooling. Other important heat management strategies relate to reducing personal exposure to heat, public health, and emergency preparedness. Planners can take a leading role in coordinating heat management efforts, but they will need to work closely with the energy sector (e.g., electric utilities), public health professionals, and emergency managers to implement these strategies.

This chapter discusses specific heat management strategies and real-world examples of where they have been implemented and evaluated for each category of heat management: energy, personal exposure, public health, and emergency preparedness. The sidebar on p. 63 shows how these strategies can be integrated into a community to manage heat.

ENERGY

Indoor cooling is one of the most important ways to reduce heat-related illnesses and deaths, but it requires reliable and affordable access to energy. Effective heat management also requires a resilient electricity grid (Figure 6.1) and electricity and indoor cooling systems that are accessible and affordable for all.

Resilient Energy Grids

Resilient energy grids are robust in responding to extreme weather, use diverse energy sources, have spare capacity to meet demand increases, and can be flexibly managed (USGCRP 2018).

Energy grid resilience is critical to urban heat resilience because the demand for electricity to support indoor cooling increases during extreme heat events, making "brownouts" and power outages more likely and more dangerous. The number of major blackouts in the United States has been increasing in recent years, and almost half occur during the months of May to August, the hottest quarter of the year (Stone, Mallen, Rajput, Broadbent, et al. 2021). When researchers modeled what would happen if a blackout occurred during a heat wave in Atlanta, Phoenix, or Detroit, they found that most residents would experience temperatures in their homes that would put them at risk of heat illness (Stone et al. 2021).

There are multiple ways of increasing energy grid resilience. Options include adding decentralized, redundant power with renewable energy microgrids, or establishing smart demand-side management programs that incentivize or

Figure 6.1. The Crescent Dunes Solar Thermal Facility in Tonapah, Nevada, uses solar photovoltaics and molten salt technology to provide renewable energy day and night (NREL/Flickr (CC BY-NC-ND 2.0))

ENVISIONING A COMMUNITY WHERE URBAN HEAT IS MANAGED

What would a community that proactively manages heat look like? Figure 6.2 integrates the heat management strategies discussed throughout this chapter to visualize how they could come together. Energy, personal exposure, public health, and emergency preparedness strategies have been integrated to manage heat risk. Here, different forms of renewable energy (rooftop solar and wind) power the community and buildings are cooled by energy-efficient air conditioning. Shade structures, trees, and the use of sunbrellas help reduce personal heat exposure for pedestrians and children playing outdoors. Public health interventions include informational signage and reusable water bottle distribution. Finally, a resilience hub serves as a shelter during an extreme heat emergency and provides additional community resources and services.

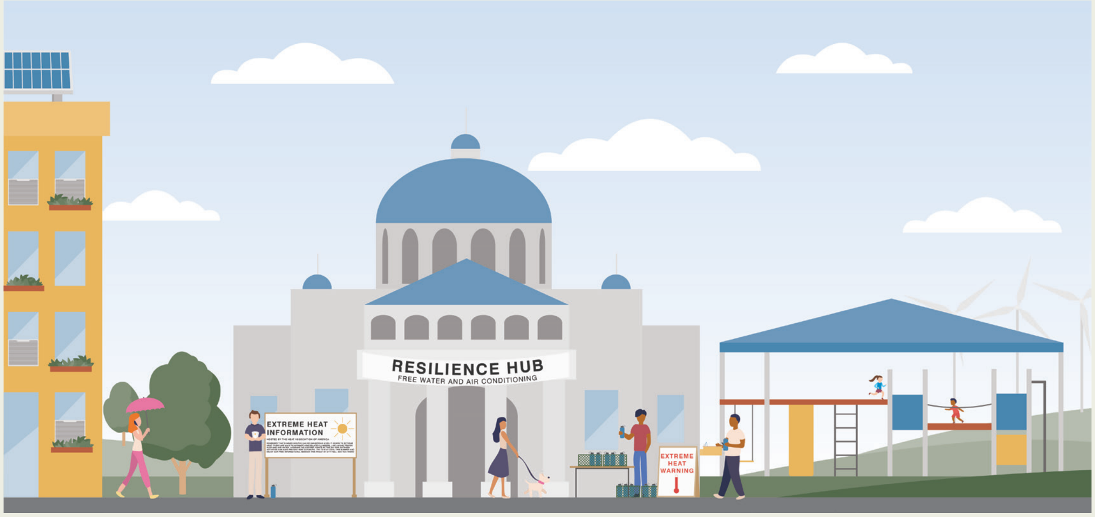


Figure 6.2. Heat management strategies within a community (Ladd Keith and Sara Meerow)

remotely implement reduced power use by certain customers during high-demand periods, thereby easing the strain on the grid (Stout et al. 2019).

In all cases, planners must work closely with energy utilities, which operate distribution and transmission lines, as well as with power generators, many of which are private companies. Regional transmission organizations, independent system operators, and federal regulators such as the Federal Energy Regulatory Commission are critical partners in enhancing grid resilience in the United States. Planners should also work with energy providers to update building codes that account for and safely allow for emerging technologies, such as garage electric car charging units and backup energy storage batteries.

Indoor Cooling

Indoor cooling, which comprises a variety of air conditioning units, evaporative coolers, and fans, is critical for preventing heat-related illness and death because people in the United States spend the vast majority of their time indoors (Wright et al. 2020).

Access to indoor cooling remains highly unequal, however, because purchasing, maintaining, and operating cooling systems can be costly. For example, one study showed that across the cities of Detroit, Chicago, Minneapolis, and Pittsburgh, half as many Black households had central air conditioning as white ones in the 1990s, and this disparity was associated with higher heat-related deaths (O'Neill, Zanobetti, and Schwartz 2005).

INDOOR COOLING IN ARIZONA

Indoor cooling can be a matter of life or death in Arizona, where summer temperatures routinely reach triple digits. The state and several cities have policies to ensure that all residents have indoor cooling.

In 2018, a 72-year-old woman in Phoenix died in her home after the utility company shut off her power because of an unpaid balance on a day when it was 107°F (41.7°C). Public outrage over this avoidable death led the Arizona Corporation Commission to change its policies in 2021 to prevent power shutoffs to customers due to lack of payment. Utility companies now have the choice between a shutoff moratorium between June 1 and October 15 or prohibiting shutoffs when temperatures reach 95°F (35°C).

The cities of Phoenix (City Ordinance G-6008) and Tucson (Tucson City Code Section 16-11(b)(2)) require that all rental units have air conditioning that cools to 82°F (27.8°C) or evaporative coolers that cool to 86°F (30°C). While temperature maximum policies are not widely established outside of Arizona, many other locations already have temperature minimum policies for rental units. Temperature maximum policies should be explored by other states and cities concerned about increasing temperatures.

Planners can help ensure equitable access to indoor cooling for renters by updating landlord regulations to include temperature maximums, as is required in the State of Arizona. The sidebar above provides more information on Arizona's requirements. Requirements for indoor cooling are also important for institutions, especially those where vulnerable community members spend time, such as schools or child- and elder-care facilities. Planners can also explore programs that subsidize the cost of purchasing and installing cooling systems for low-income residents, such as in New York City (see the sidebar in Chapter 4, p. 45).

Figure 6.3. "Heat Kills" sign in Boulder City, Nevada, referencing a city ordinance to discourage drivers from leaving children in parked cars (JStephenConn/Flickr (CC BY-NC 2.0))

Affordable and Accessible Energy

Providing indoor cooling to all community members is only effective if they can afford the electricity required to keep their homes cool. Energy insecurity, or the inability of households to meet basic needs, is a challenge for many low-income residents, with nearly 4.8 million U.S. households unable to pay one energy bill during 2020 (Memmott et al. 2021).

While most homes in hot climates like the U.S. Southwest have some form of air conditioning, lower-income residents may need to sacrifice other necessities to keep their indoor temperatures comfortable and safe (Wright et al. 2020). One way to address energy insecurity is through programs that ensure all residents can afford the cost of indoor cooling on their electricity bills. Another is to reduce the cost of that cooling by increasing energy efficiency.

Utility assistance programs are designed to help low-income residents pay their energy bills. The U.S. federal government provides the Low Income Home Energy Assistance Program (LIHEAP), which is administered through each state. In addition, utilities, local governments, and nonprofit organizations may have their own programs. As noted above, it may also be possible to restrict the ability of utilities to shut off power to a residence that is delinquent on their payments during the hottest times of the year, as is now the case in Arizona (see the sidebar above).

The cost of indoor cooling depends greatly on building characteristics, such as insulation and site orientation, as well as the efficiency of appliances (Stone et al. 2021). Weatherization programs that subsidize retrofits of existing buildings (e.g., adding insulation, repairing air conditioning ducts, or repairing windows) can help to increase the energy efficiency of homes where lower-income residents live. The U.S. Department of Energy provides some weatherization assistance, as do some local governments and utilities (McCormick and Ganthier 2021).

PERSONAL EXPOSURE

Reducing individual exposure to dangerous levels of heat may require alterations to public infrastructure and facilities such as transit stops, hiking trails, and playgrounds; changes to ordinances (Figure 6.3, p. 64); and regulations for indoor and outdoor worker safety.

Transit System Operations

Heat risks should be considered in not only the planning and design of public transit systems, but also in their operation.

Bus or other transportation stops should be shaded, either with trees or shelters, as this increases the thermal comfort of people using them and makes it less likely that surfaces reach temperatures that can burn skin (Dzyuban et al. 2021). Adding misters or water fountains and choosing materials that do not conduct heat could also be effective.

In addition to these design strategies, the operation of transit systems is critical in reducing personal heat exposure of transit users. Frequent and reliable service can decrease personal heat exposure time at stops, and alert systems for delays should be easily findable by members of the public—particularly during extreme heat events when waiting outside for extended periods of time is even more dangerous.

School Operations

Like transportation infrastructure, school buildings and facilities should be designed or retrofitted to increase thermal comfort and operated in ways that decrease heat exposure.

Playgrounds and other outdoor areas should be shaded. Research shows that playground materials exposed to direct sun can heat up enough to cause burns, but shading with trees, shade sails, or even school buildings can effectively reduce those temperatures while also helping to reduce harmful UV radiation (Vanos et al. 2016). Individual schools and school districts can also create rules about what temperatures students can be outside in and for how long, adjusting recess or physical education schedules and activities as needed to reduce the risk of heat-related illnesses and deaths.

Figure 6.4. Trail signage at South Mountain Park in Phoenix educates city hikers on heat safety to prevent heat illness (Sara Meerow)

State and local health departments and school districts should be key partners in these efforts. In Arizona, for example, the Department of Health Services provides school heat alerts and heat toolkits to schools (Arizona Department of Health Services 2021).

Parks and Trails Operations

During periods of extreme heat, communities may want to discourage some forms of outdoor recreation to reduce heat-related illnesses. For example, in Maricopa County, Arizona, hundreds of people are rescued each year while hiking, many of them because they suffer heat exhaustion or stroke. Therefore, the City of Phoenix and Arizona tourism organizations developed a campaign—"Take a Hike. Do it Right"—in which they placed signs at trailheads and on websites reminding hikers about heat dangers and encouraging them to stay hydrated (Figure 6.4) (Gonzalez et al. 2018). The city's parks and recreation department also closes some of the most popular yet challenging trails on days when the National Weather Service issues an Excessive Heat Watch.

Planners can advocate for similar policies aimed at reducing heat exposure in their communities and work with other local officials, such as those in the transportation, parks and recreation, and public health departments as well as the school board, to implement them.

Occupational Safety Regulations

Hundreds of workers have reportedly died from heat exposure in the United States over the last decade, with most of these

CALIFORNIA OUTDOOR WORKER REGULATIONS

In 2005, California became the first state to pass heat regulations for outdoor workers. The Heat Illness Prevention in Outdoor Places of Employment standard requires that employers provide training for employees on acclimatization and preventing heat illness, drinking water, and shade and rest breaks for employees when the temperature exceeds 80°F (26.7°C).

In addition, employers must write a Heat Illness Prevention Plan that includes these provisions as well as emergency response procedures and disseminate it to employees. When temperatures reach 95°F (35°C), heat procedures must be enacted, which should include enhanced observation for symptoms of heat illness and mandatory 10-minute breaks every two hours for cooling down.

One study evaluating California farms found generally high compliance with the regulations, but despite trainings, many of the farm workers lacked knowledge about heat risks (Langer et al. 2021). This suggests a need for more educational efforts, for example, through signage like that shown in Figure 6.5. While improvements could still be made to these regulations, as OSHA develops federal heat standards for workers, they are looking to California as a model.

Figure 6.5. Signage, available in both English and Spanish, from the State of California to educate workers about their heat safety rights (State of California)

Figure 6.6. A heat safety graphic from the National Weather Service aimed at increasing public awareness of extreme heat (U.S. NOAA)

deaths occurring on days where the temperature was above 90°F (32.2°C) (Shipley et al. 2021).

The U.S. Occupational Safety and Health Administration (OSHA) has not traditionally had a heat standard, but the National Institute for Occupational Safety and Health (NIOSH) has a recommended standard that includes training on heat risks and acclimatization periods for new workers, as well as requirements for water, shade, breaks, and medical monitoring when it is hot (Jacklitsch et al. 2016). In September 2021, the White House announced plans for OSHA to implement an enforcement initiative on heat and to create a National Emphasis Program related to heat inspections, a working group on heat, and eventually a workplace standard (U.S. Department of Labor 2021).

California was the first state to pass a heat standard (see the sidebar on this page), followed by Minnesota and Washington. Oregon also enacted a temporary law in the wake of an unprecedented heat wave in June 2021. In all cases, these policies require that outdoor workers be allowed to acclimatize to the heat and be given consistent breaks, drinking water, and shade.

Employees should also be informed of the risks of heat illness and how to recognize symptoms. Similar policies could be adopted by any local government or private employer, especially those such as landscaping or construction companies whose employees work outdoors. Planners can help advocate for this in their communities.

PUBLIC HEALTH

As heat risks increase, the public needs to be educated and informed about the dangers of heat and how to avoid

IMPROVING HEAT HEALTH IN EL PASO COLONIAS

In 2018, researchers at the University of Texas at El Paso and the University of Arizona worked to help increase resilience to the public health risks of extreme heat for colonias residents in the Del Norte (El Paso–Juarez–Las Cruces) US–Mexico border region. Colonias residents are highly heat vulnerable, living in informal communities with substandard housing and frequent energy interruptions. A large proportion of colonias residents are outdoor workers.

The researchers worked directly with promotoras, locally trusted healthcare providers, to improve public health education about extreme heat directed at maternal health and outdoor workers. This project connected climate and health researchers with local promotoras, and ultimately engaged the community to ensure information created would be useful for intended audiences. In addition to the freely available curriculum of bilingual English-Spanish brochures and flyers on heat safety, a hydration urine color chart (Figure 6.7) was a popular outcome that allowed outdoor workers to monitor their own health.

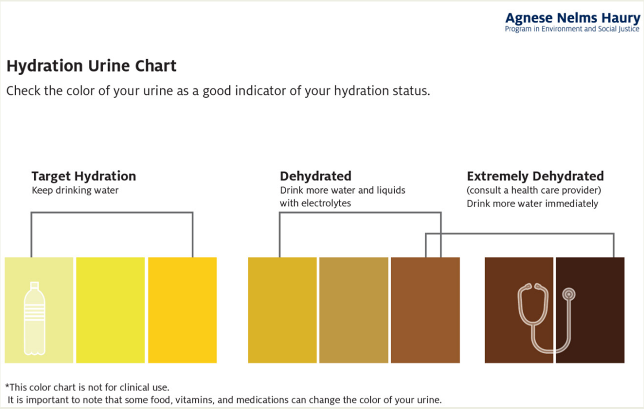


Figure 6.7. A hydration urine chart, available in both English and Spanish, posted in restrooms to educate community members about how to monitor their own health (Agnes Nelms Haury Program)

them—especially because heat is an invisible hazard. Public information and awareness campaigns (Figure 6.6), as well as information distributed to healthcare providers, can help.

Public Information and Awareness Campaigns

Heat information campaigns should communicate the various risks that heat poses to community members, and they should also outline actions people can take to address the problem. Research shows that public health campaigns that simply appeal to people's fears without providing effective ways for them to respond are less successful (Witte and Allen 2000).

Figure 6.8. Community spaces, such as the East County Health Center in Portland, Oregon, are increasingly being made available as cooling centers during extreme heat events (Multnomah County)

Planners can coordinate with public health staff and other organizations to ensure that consistent heat information is disseminated before the hot season through different channels, including government websites, social media, and partnerships with local news media, and at locations such as public libraries, parks, transit stations, and schools. Information should be provided to community members about the ways they can keep themselves and their homes safe from heat, as well as where they can go for assistance, such as cooling centers. Visualizations and multimedia should be incorporated into these materials, information should be tailored to different audiences, and it should be offered in different languages to reach all members of the public (GHHIN 2021).

Heat Awareness for Healthcare Providers

Healthcare providers, who tend to be highly trusted sources of information, are important partners in educating the public about heat health risks and their mitigation and management (Maibach, Frumkin, and Ahdoot 2021).

Planners can work with public health departments and professional organizations representing healthcare providers to disseminate heat-related resources and encourage them to discuss heat with their patients. One such example from El Paso is discussed in the sidebar above. As another example, the Maricopa County Health Department in Arizona emails case managers that work with individuals with mental illness, suggesting that they remind patients to stay hydrated during extreme heat events (White-Newsome et al. 2014).

EMERGENCY PREPAREDNESS

Communities should ensure their emergency management systems are prepared for unprecedented extreme heat events by planning coordinated responses for emergencies, developing early warning systems, and establishing cooling centers or resilience hubs across the community (Figure 6.8, p. 67) where people can go for shelter and assistance.

Heat Response Planning

Unprecedented heat waves around the world in recent years have made it clear that all communities, regardless of past experience with heat, should have a plan to respond to extreme heat events. Yet many cities do not (Bernard and McGeehin 2004).

In heat response planning, communities develop a set of coordinated steps government agencies and other partners will take during an extreme heat event to prevent heat-related illnesses and deaths (Abbinett et al. 2020). While heat response planning is often led by public health departments, many other agencies and partners may participate, including planning departments, emergency management organizations, hospitals and healthcare groups, universities, school districts, utilities, faith-based organizations, the National Weather Service, and more. Planners can assist public health departments in planning by sharing vulnerability information and heat mapping data.

Specific heat response planning actions differ by location, but commonly include increased surveillance for heat-related illness or emergency visits, heat-related public communication, increased social services, outreach to vulnerable individuals, cooling centers, water and fan distribution, and energy assistance (Abbinett et al. 2020).

There is some evidence that heat response planning reduces heat deaths. France implemented a National Heat Wave Plan in 2004 after thousands of excess deaths were linked to the 2003 European heat wave. When another severe heat wave occurred in 2006, significantly fewer people died, suggesting that planning, as well as the associated warning system, may have had an effect (Fouillet et al. 2009).

Early Warning Systems

Heat early warning systems provide a community with advance notice of when an extreme heat event is forecasted. These warnings can be used to trigger actions across government agencies and organizations (i.e., those outlined in a heat response plan) aimed at minimizing negative impacts.

The National Weather Service (NWS) issues four general categories of heat warnings based on the Heat Index, which are widely adopted by communities across the United States:

- **Excessive Heat Outlook:** 3–7 days in advance of a potential excessive heat event
- **Excessive Heat Watch:** 24–72 hours in advance of an excessive heat event
- **Heat Advisory:** 12 hours before the maximum Heat Index is over 100°F (37.8°C) for two or more days and air temperatures at night will not drop below 75°F (23.9°C)
- **Excessive Heat Warning:** less than 12 hours before the

Figure 6.9. An information flyer from Baltimore City Health Department's Code Red program (City of Baltimore)

maximum Heat Index is expected to be over 105°F (40.6°C) for two or more days and air temperatures at night will not drop below 75°F (23.9°C)

The temperature thresholds for these warning levels vary across the country because some places are more acclimatized to heat than others. In areas of consistent high heat and humidity, heat warning systems may need to be customized to reflect the chronic heat risk.

Planners should advocate with public health and communication staff for heat warnings to be widely communicated through different channels, including television, radio, public websites, social media, email lists, and text messages. Since the most vulnerable community members are often the hardest to reach (Abbinett et al. 2020), physical signage in public locations and messaging coordination with key social service providers and community workers is also critical.

The federal government provides materials that localities can use to communicate heat risk through the NWS, CDC, and FEMA. For example, Ready.gov offers an Extreme Heat Safety Social Media Toolkit with heat safety and preparedness messages that local governments and organizations can share through their social media channels.

In Baltimore, the health commissioner activates the city's "Code Red" program during periods of extreme heat when the air temperature and relative humidity are greater than or equal to 105°F (40.6°C) (Figure 6.9, p. 68). City agencies collaborate with health officials, local media, cooling center providers, and the NWS to streamline public communications and reach vulnerable community members to ensure messaging is consistent (Martin 2016). Once a Code Red is declared, a consistent set of actions is set into motion, including a coordinated awareness campaign, additional safety precautions for shelters, activation of cooling centers, and drinking water distribution.

Data on the effectiveness of early warning systems in changing behaviors and preventing heat-related morbidity are limited, but several studies associate them with reduced mortality (Toloo et al. 2013). For example, one study estimated that Philadelphia's warning system saved 117 lives in the three years after it was implemented in 1995 (Ebi et al. 2004). Current heat warning systems are based on specified heat thresholds, but work is being done to explore warnings specified instead based on projected impacts to human health and life (Potter, Harrison, and Kreft 2021).

Cooling Centers and Resilience Hubs

Cooling centers are designated locations where people can go to seek assistance and shelter from extreme heat. They are usually established in buildings with indoor cooling, including publicly owned libraries or schools or privately owned community centers, places of worship, shopping malls, or convention centers. Some outdoor spaces such as fountains or pools may also serve as cooling sites (Widerynski et al. 2016).

Cooling centers can be administered by different organizations, including public health agencies, city government, or nonprofits. Heat response plans should clearly identify when cooling centers should be opened, their locations, and who is responsible for running them.

While research clearly shows that having access to cooled spaces during heat events reduces mortality risks, few studies have directly evaluated the effectiveness of cooling centers (Widerynski et al. 2016). One study of cooling centers across Maricopa County, Arizona, found that they served more than 1,500 people per day, largely from vulnerable community groups, and at relatively little additional operating cost (Berisha et al. 2017).

When planning cooling centers, it is important to consider that the residents who need them most may lack personal transportation, have pets that they are unwilling to leave behind, or also need shelter at night or on weekends, when it may still be dangerously hot but many places used as cooling centers are closed. Cooling centers should be strategically located near vulnerable groups, and if possible have backup power sources (e.g., rooftop solar) sufficient to power air conditioning if there is a power outage on the grid. Planners can use GIS to identify optimal locations based on a heat vulnerability index, as one study showed for Pittsburgh (Bradford et al. 2015).

It is also important to widely communicate the locations of cooling centers. For example, in 2018 as part of the city's "We're Cool" initiative, volunteers in Phoenix distributed heat safety information, water, and cooling center maps to vulnerable groups (Singh et al. 2019).

An increasingly popular concept is resilience hubs, or community-serving facilities that support residents and coordinate communication and resources before, during, and after disruptions (Baja 2018). Resilience hubs are established in existing, trusted neighborhood locations, and can be stocked with emergency supplies, equipped with their own energy sources, and set up to provide additional community services.

While designed as a refuge for all emergencies, resilience hubs can also be easily designated as cooling centers. Baltimore was one of the first cities to establish resilience hubs. Locations developed through the Community Resiliency Hub Program, led by Baltimore's Office of Sustainability within the Department of Planning, and through which the city government partners with community-based organizations, have already served as cooling centers, while also providing flooding relief and serving as COVID-19 testing and vaccine distribution sites (Brey 2021). Resilience hubs, therefore, have the potential to provide multiple community co-benefits and could represent a low- or no-regret heat resilience strategy—and as discussed in Chapter 4, it is wise to prioritize such strategies.

CONCLUSION

Extreme heat events will continue to worsen in the coming years, and planners should collaborate with public health officials, emergency managers, the energy sector, and many other partners to plan and respond to chronic and extreme heat events in their communities through strategies related to energy systems, personal exposure, public health, and emergency management.

Planners can provide critical information and mapping, help promote policies and programs that enhance the resilience of the electricity grid, increase access to indoor cooling, and make electricity more affordable through utility assistance and weatherization. By working with partners to change the way transportation systems, schools, and parks and recreation facilities are operated when it is hot and enact heat standards for workers, planners can help to reduce people's exposure to heat. Planners should also collaborate with public health officials to develop effective heat information and awareness campaigns. Finally, communities should develop heat response plans that outline sets of actions—activated by early heat warning systems—to minimize the impacts of extreme heat events.

The following chapter delves deeper into how the heat mitigation and management strategies outlined in this and the previous chapter can be integrated into existing urban planning activities, processes, plans, and regulatory tools.

CHAPTER 7

PLANNING TOOLS FOR URBAN HEAT RESILIENCE

As the previous two chapters demonstrate, there are many approaches that communities can use to mitigate or adapt to extreme heat, and in doing so, enhance urban heat resiliency. To assist their communities in these efforts, planners should work to integrate relevant urban heat mitigation and management strategies into their existing activities, processes, plans, and regulatory tools.

Planners in many communities have begun this work, but there are many additional planning tools that could be applied to enhance urban heat resilience. In the survey of planners across the United States mentioned in Chapter 1, 87 percent of respondents reported implementing at least one heat mitigation or management strategy in their community (Meerow and Keith 2021). The most popular heat mitigation strategy was urban forestry and vegetation, reportedly used by 73 percent of planners surveyed (Meerow and Keith 2021). However, only nine percent of surveyed planners reported addressing heat in zoning codes and regulations, and 10 percent addressed heat in building codes. Addressing heat throughout planning policy tools—especially those that shape the future built environment, such as zoning codes and regulations—is an opportunity area for the planning profession. While 65 percent of planners reported addressing heat in at least one community plan, this was spread across various plan types, with no single plan type addressing heat in most communities (Meerow and Keith 2021).

This chapter covers how planners can better integrate heat planning into a wide range of local government processes, documents, and actions: community visioning and engagement, plans and policies, regulations and project reviews, and public investments. While heat planning is still an emerging area, this chapter offers specific suggestions drawing from existing heat planning practices and other areas of climate change and hazards planning.

Table 7.1 (p. 73) summarizes the categories of heat management and mitigation strategies discussed in Chapters 5 and 6 and lists the processes, documents, and actions described in this chapter to create an urban heat resilience planning matrix. Planners can use it in several ways: for example, as an audit tool to review which local planning interventions already contain heat mitigation and heat management strategies, or as a framework to consider where and how these strategies could be added to existing planning interventions. It can help planners make use of the full suite of planning and regulatory tools and strategies available to address urban heat resilience.

COMMUNITY VISIONING AND ENGAGEMENT

A key role of the planning profession is inclusively engaging the public in local decision-making. This is particularly critical for a topic like heat, which the public is generally less familiar with than other hazards. Not all communities have experienced extreme heat events yet, and as noted in prior chapters, heat impacts are often largely invisible to those who are not directly impacted, unlike more visible hazards such as wildfires, urban flooding, sea level rise, and hurricanes.

Planners have an important role in community engagement to help frame heat as a risk that communities should actively address. Planners should ensure they have the best available historical climate data, climate projections, currently known impacts of heat, and heat vulnerability information. They should also coordinate with other professionals critical to urban heat resilience, such as public health professionals, as interdisciplinary climate initiatives lead to more collaborative projects over time (Austhof et al. 2020).

In communities that have historically not been impacted by heat, the challenge is often to raise awareness

TABLE 7.1. URBAN HEAT RESILIENCE PLANNING MATRIX

	Heat Mitigation Strategies				**Heat Management Strategies**			
	Land Use	**Urban Design**	**Urban Greening**	**Waste Heat**	**Energy**	**Personal Exposure**	**Public Health**	**Emergency Preparedness**
Community visioning and engagement								
Plans and Policies								
Comprehensive or general plan								
Subarea and district plans								
Climate action, adaptation, resilience, and sustainability plans								
Hazard mitigation plans								
Emergency management plans								
Public health plans								
Heat action and response plans								
Regulations and Project Review								
Zoning and land-use regulations								
Streetscape design guidelines								
Building codes								
HOA regulations and CC&Rs								
Public Investments								
Parks, open space, and connections								
Flood management infrastructure								
Transportation and transit infrastructure								
Public buildings								

for heat risk and not wait until a disaster occurs to take action. In these cases, planners can point to examples where cooler communities were caught off guard, such as those in the Pacific Northwest during the June 2021 heat wave (see the sidebar in Chapter 1, p. 11). In contrast, for communities that have always faced high temperatures, there is a tendency to downplay heat as something that has always been an issue. Raising awareness about its existing and increasing impacts should be a focus for these communities.

While the equity implications of heat should be at the center of these discussions, it is also important to frame heat as a risk that affects everyone. Heat can be experienced very differently across a community, so seizing opportunities to discuss and learn about those different experiences is vital. Planners should keep in mind that most residents do not currently think about heat risk explicitly, but it likely already influences their lives in subtle ways that can be made explicit. Planners can help raise awareness about how heat connects to everyday activities, such as when residents are comfortable waiting at a bus stop, when they can walk their dogs, or what time of day they take their children to a park.

In addition to raising awareness and increasing education, planners should make full use of proven inclusive engagement practices to help identify appropriate heat mitigation and management strategies. The communities and residents most impacted by heat are often those historically left out of public participation processes, so planners must take extra care to include them in the development of community visions for urban heat resilience and the strategies that will advance that vision. For example, planners can help their communities better understand the relationship between the location of new green infrastructure investments and heat mitigation benefits. In addition, many heat mitigation and management strategies have co-benefits for other community goals, such as using green stormwater infrastructure to reduce both heat and flooding. In these instances, planners can help better articulate the heat co-benefits for existing goals and activities.

One example of how planners can engage community members on heat is the [U.S. NIHHIS Urban Heat Island Mapping Campaign](). In this program, participant cities help plan and then coordinate volunteer-based community science field campaigns that engage residents and community organizations in participatory UHI mapping activities. The maps produced help residents and decision makers better understand how heat is spatially distributed in their communities. Planners can use opportunities like this to gain helpful decision-making information and engage and educate their communities on the topic of heat.

Figure 7.1. In this Nature's Cooling Systems workshop in Phoenix, advisors introduce information on heat to community members (Melissa Guardaro (CC BY-NC-ND 4.0))

Finally, as with engaging the community for any complex planning topic, planners should prepare their engagement materials with an eye to the audience's familiarity with heat as a climate risk. If heat is a new planning topic for the community, informational presentations to help increase awareness may be a helpful first step. In Nature's Cooling Systems workshops held in Phoenix, heat experts or "advisors" worked with community members and decision makers in a variety of workshops aimed at engaging residents on heat risk and strategies (Figure 7.1) (Guardaro et al. 2020). Planners may also want to seek opportunities to discuss heat in more technical terms with officials and leaders working in public health, social services, emergency management, and utility functions, as well as local weather and climate service providers.

PLANS AND POLICIES

As discussed in Chapter 4, urban heat resilience and the seven practical considerations for holistically addressing urban heat resilience in planning principles listed on p. 38 should be integrated across a community's network of plans. In addition to a community's comprehensive plan, heat should also be addressed in hazard mitigation plans, climate action plans, parks and recreation plans, transportation plans, and other relevant plans.

Communities can also address heat in other policy documents, such as urban design or streetscape design guidelines and green infrastructure design policies.

Planners can coordinate with allied disciplines to provide information and strategy recommendations for public health plans and emergency management plans.

Across all of these plans and policies, planners should use clear and consistent language on heat. The same fact base can be shared as relevant across plans, including information on historical climate data, climate projections, urban heat island (UHI) maps, vegetation maps, and public health data.

Best practices for plan implementation should also be followed, including identifying departments responsible for implementing policies, funding sources, timelines for action, and evaluation metrics or criteria.

Comprehensive Plans

As noted in Chapter 4, comprehensive plans provide the overarching vision and policy guidance for a community and offer the opportunity for a community to address heat across all relevant planning topic areas. The comprehensive plan should serve as the foundational local policy document for a community's vision of its future.

Comprehensive plans should summarize relevant heat information, particularly related to regional climate change projections and impacts, and should identify areas of the community that have higher heat severities. Comprehensive plans should also outline heat-related goals, such as ensuring future development does not exacerbate the UHI effect or being prepared to manage extreme heat events. Examples of heat-related objectives could include the following:

- Increasing shade along pedestrian areas and public spaces
- Reducing land surface temperatures as shown on UHI maps
- Reducing heat-related illnesses and deaths
- Improving housing weatherization and energy efficiency
- Reducing waste heat from vehicles and air conditioning

Many policies that can help achieve heat-related goals and objectives are likely already in existing comprehensive plans, such as increasing the walkability of neighborhoods (which has a vehicle waste heat reduction co-benefit) or the use of green stormwater infrastructure (which has a heat reduction benefit). Additional policies addressing heat could relate to requirements for cool roofs and cool pavement coatings, ventilation corridors, or shade in streetscape design guidelines.

Finally, future land-use planning maps should also consider heat through conservation of existing natural or rural areas and strategically increasing green space within urban areas where possible. Increased density does not necessarily increase the UHI effect, but heat mitigation strategies should be taken into account when an area on the land-use planning map is designated for intensification.

A primary decision for planners is whether heat will be integrated across the comprehensive plan, focused within a specific element, or addressed through a combination of both approaches. If there is a specific element for heat, or more broadly for climate change, it is important to make sure that for other relevant goals and policies elsewhere in the plan, their heat resilience co-benefits are explicitly stated. This is critical for the goals and policies that have less well-recognized heat mitigation and management benefits.

Regardless of approach, planners can consider including a matrix within the comprehensive plan that explicitly ties goals and policies to heat and other climate risks, to both raise awareness of the connections as well as provide a quick reference to relevant policies.

Subarea and District Plans

Subarea and district plans lay out visions for distinct areas within the larger community on a smaller and more detailed scale than comprehensive plans. Similar to comprehensive plans, subarea and district plans often cover a variety of elements that are relevant to heat resilience planning, including land uses, transportation, parks, and connections, and often address more urban design-oriented aspects such as building massing, shape, and features.

Because they provide a greater level of detail for specified areas, subarea and district plans are appropriate plans to further target heat mitigation and management strategies to where they are needed most. For example, they can lay out exactly how shade will be increased for pedestrians and bicyclists, identify locations within the plan area to prioritize heat mitigation strategies such as increased urban greening or use of cool surfaces, or identify heat-vulnerable community members who may need more assistance.

Functional Plans

As described in Chapter 4, communities often have a variety of functional plans, or plans that focus on a specific topical area, that are relevant for heat resilience.

- **Strategic plans** that are used by municipalities to prioritize various initiatives and operations can integrate heat mitigation and management into their goals, objectives, performance metrics, and implementation.

- **Parks and recreation plans** often specify improvements to open spaces and connections within a community and can help planners strategically prioritize urban greening efforts in neighborhoods with higher heat severities.
- **Flood management plans** also often intersect with open space and green stormwater infrastructure investments, which can have heat mitigation benefits.
- **Transportation plans** are critical as transportation infrastructure can unintentionally increase the UHI effect, so policies to reduce impervious surfaces such as roadways and parking lots can assist with heat mitigation efforts. Transportation plans may also be used to specifically identify future cool corridor routes where shade and other cooling strategies are prioritized to increase the safety of pedestrians and bicyclists.
- **Regional plans**, often environment- or transportation-related, are also important planning documents in which to address heat because the UHI effect is a regional phenomenon, and they may offer opportunities to collaborate regionally on heat mitigation efforts.

Two other key relevant functional plan types are climate action, adaptation, resilience, and sustainability plans and hazard mitigation plans.

Climate Action, Adaptation, Resilience, and Sustainability Plans

Many communities have already adopted climate action, adaptation, resilience, or sustainability plans. While the titles are often used interchangeably, climate action plans focus on the mitigation of greenhouse gas emissions and sometimes also on preparing and responding to climate impacts. Adaptation and resilience plans both focus on the preparation for and response to climate impacts. Sustainability plans typically focus on energy efficiency, renewable energy sources, and resource management. These plan types are frequently more technical than comprehensive plans, with more detailed information. For instance, climate action plans include detailed historical and projected climate changes, anticipated impacts, and vulnerability assessments.

Planners should address heat specifically in all of these plan types, which in most cases already incorporate many of the critical information sources that inform heat planning. Additional information such as UHI maps, heat-related health data, housing quality and indoor cooling availability, and emergency preparation protocols for extreme heat events should also be included.

Despite the more technical nature of these plans, community members should still be engaged in these planning processes (Figure 7.2). Specific policies relating to municipal operations may also be appropriate for these plans; for example, the creation of an interdepartmental heat task force with regular meetings, or the creation of a chief heat officer position within the local government or heat office.

Unlike comprehensive plans, climate action, adaptation, resilience, and sustainability plans are not commonly used in the development review process, so any relevant land use-related policies should be identified in an appendix to be considered for inclusion in future comprehensive plan updates.

Hazard Mitigation Plans

The U.S. Federal Emergency Management Agency (FEMA) requires that all state, tribal, and local governments develop and adopt hazard mitigation plans focused on reducing risk to natural hazards to be eligible for funding. Local hazard mitigation plans can be developed jointly by counties and include multiple municipalities, or they can be developed independently by municipalities.

Local governments are required to adopt hazard mitigation plans that identify relevant hazards to be eligible for FEMA post-disaster funds and for grant opportunities such as the Hazard Mitigation Grants Program. Emergency management departments often lead hazard mitigation planning or are closely connected to their development and implementation, but planners can

Figure 7.2. Community open house for Flagstaff, Arizona's climate action plan, where increasing heat is a concern for residents (City of Flagstaff)

and should also be involved in such efforts, as described in PAS Report 560, *Hazard Mitigation: Integrating Best Practices into Planning* (Schwab 2010).

Although historically little FEMA funding has been awarded to address heat, this may change in the coming years as awareness of heat risk grows. Heat must be included in a hazard mitigation plan to be eligible for certain FEMA funding that does address heat risks. This requires including a profile of heat as a hazard, which should include both historical and projected climate data, as well as any available impacts to the community. Strategies to reduce heat as a hazard must also be identified and included. While many communities across the United States do identify extreme heat as a hazard, very few include specific heat mitigation actions in their hazard mitigation plans, which is a missed opportunity for communities to pursue federal funding to mitigate heat in the built environment.

As with climate action plans, hazard mitigation plans are often not well linked to comprehensive plans (Woodruff et al. 2021), but through more strategic engagement, the two plan types can inform each other and strengthen heat mitigation efforts.

The FEMA website for hazard mitigation planning provides additional guidance.

Emergency Management Plans

While emergency management plans are developed outside of urban planning practice, they are an important piece of a community's heat resilience. Emergency management plans articulate how a community plans and responds to a variety of emergencies. This is relevant to heat in the case of extreme heat events as well as other cascading disasters, such as disruptions to the energy grid that increase vulnerability to heat risk.

Emergency management plans often include information about the operations and coordination that takes place once an emergency is declared. In the case of extreme heat, this may be triggered by heat warnings issued by the National Weather Service.

Emergency management plans and planning efforts are also a critical connection to first responders such as the police, firefighters, and medical personnel. All communities should include extreme heat in their emergency management plan because, as emphasized throughout this report, the likelihood, intensity, and duration of extreme heat events is increasing due to climate change.

Planners can help inform emergency management plans by identifying neighborhoods with higher heat severity and providing information on transportation access and reliability, housing quality and prevalence of indoor cooling, and other factors critical to understanding heat risk during an extreme heat event. Likewise, planners can be informed by emergency management plans to understand better which public facilities are being identified as locations for cooling centers or resilience hubs and which community members have been identified as vulnerable during extreme heat events by frontline responders.

Emergency management planning is also a key area where coordination with utilities such as energy providers is critical to ensure the energy grid remains reliable even during peak demand periods due to heat. Emergency protocols should be in place in the event of a widespread and extended power outage during an extreme heat event.

The FEMA website on emergency management planning provides additional guidance.

Public Health Plans

Public health plans are also developed outside of urban planning practice but are nonetheless a critical part of a community's urban heat resilience. County public health departments often develop public health plans to improve community health outcomes, but not all health plans include climate change risks such as heat.

Similar to emergency management planning, planners can both inform and be informed by public health efforts related to heat by reaching out and connecting with public health staff. Public health departments often hold critical information related to the number, timing, and location of heat-related illnesses and deaths that can help planners better prioritize heat mitigation and management strategies.

The Centers for Disease Control and Prevention (CDC) has several initiatives to increase the use of climate information in public health planning, including the Building Resilience Against Climate Effects (BRACE) Framework (Figure 7.3, p. 78). The BRACE Framework helps incorporate climate change into public health efforts through five steps:

1. Anticipating climate impacts and assessing vulnerabilities
2. Projecting the disease burden
3. Assessing public health interventions

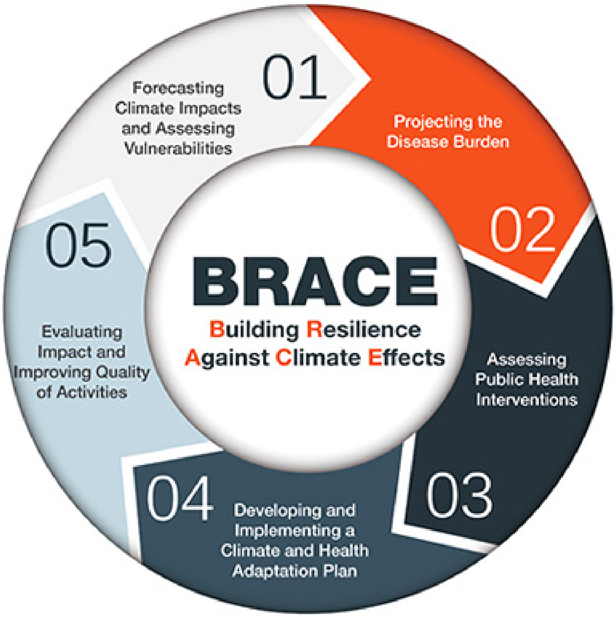


Figure 7.3. CDC's Building Resilience Against Climate Effects (BRACE) framework (U.S. CDC)

4. Developing and implementing a climate and health adaptation plan
5. Evaluating impact and improving quality of activities

These steps are all useful for better understanding and planning for heat-related health impacts. While this program is also grant funded, the steps can be followed by local public health departments based on materials provided by CDC.

The CDC's website for public health and climate planning provides additional guidance.

Heat Action and Response Plans

Heat action plans are an emerging plan type that combines aspects of adaptation or resilience plans, emergency management plans, and public health plans but are specific to heat risk.

These plans can be developed as stand-alone documents or as addendums to all-hazards plans and can address different scales, from a single neighborhood to an entire state, as well as compound risks, such as a hurricane causing power outages that is followed by a heat wave. They have been made at various levels of government. Examples include a state-level draft plan in California, a city-level plan in Ahmedabad, India, and several neighborhood-level plans from the city of Phoenix.

Heat action plans should include information on historical and projected heat data as well as identified heat vulnerabilities. Heat action plans typically also include information on early warning and response systems for extreme heat events, public awareness and education efforts, increased public health surveillance and monitoring for heat impacts, cooling center or resilience hub planning, and heat mitigation strategies (Ebi 2019).

Heat action plans bring together relevant disciplines critical to urban heat resilience in a single plan that guides community efforts. Like any highly interdisciplinary planning effort, the plan itself should link back to relevant comprehensive plans, hazard mitigation plans, climate action and associated plans, emergency management plans, and public health plans. The Global Heat Health Information Network provides heat action plan guidance and case studies.

While heat action plans can include mitigation and management, heat response plans tend to focus more specifically on management. A 2020 report from the CDC (Abbinett et al. 2020) provides detailed guidance specifically on heat response plans. The report notes that heat response plans generally do the following:

- Summarize the projected impacts of heat
- Determine the weather conditions, or heat thresholds, at which certain elements of the plan will be activated
- Identify populations or locations most at risk
- Identify specific actions to prepare for, respond to, and recover from a heat event
- Outline who is responsible for implementing these actions and what partners they will collaborate with
- Discuss how the plan will be evaluated and revised accordingly in the future

This information could also be helpful for a broader heat action plan, which includes both mitigation and response or management.

REGULATIONS AND PROJECT REVIEW

Planners should also explicitly integrate heat mitigation as a consideration into land-use and development regulations, to be enforced through development review.

These are arguably the strongest and most direct policy tools planners have to influence the shape and form of the built environment, yet they are largely unused for heat planning. Many of the heat mitigation strategies discussed in Chapter 6, such as cool roofs, increased tree canopy, and energy efficient buildings, could be integrated into existing regulations to noticeably reduce the UHI effect.

Current development requirements should also be reviewed to identify provisions that may unintentionally increase the UHI effect, such as excessive parking requirements. Design guidelines that specify requirements for streetscape or public spaces should also include provisions for shade and the use of cool surfaces, and they should establish maximums for total impervious surface coverage when possible. Environmental review processes can also include heat as a consideration to determine a project's potential impacts related to heat.

Heat planning should draw from the planning profession's experiences in integrating hazards like floods and wildfires into existing regulations and project reviews. For example, planners have called for creating flood protection infrastructure in areas that are floodprone (Schwab 2010), and local regulations typically require that new development does not increase flood risk and that structures placed in floodprone areas are floodproofed. While flood risk is different from heat risk—an entire urban area is essentially at risk for heat—new development should not contribute to heat as a hazard and should also be adapted to it.

Changing or increasing the strength of development regulations can always be a challenge, so planners must be prepared with information on heat impacts and be ready to engage community members and the private sector in determining appropriate heat mitigation strategies.

Zoning and Development Regulations

The integration of heat mitigation into zoning and development regulations is critical to reduce the UHI effect. This is true both for infill development, which can be done in such a way that increases density while minimizing existing contributions to the UHI effect, as well as for greenfield development, which should be designed and built in ways that minimize increases in the UHI effect.

Examples of considerations for zoning and development regulations include increasing landscaping requirements, reducing parking requirements, requiring cool roofs, or requiring cool roadway or parking lot coatings. For example, the accessory dwelling unit (ADU) ordinance adopted by the City of Tucson in 2021 requires cool roofs to help offset any increases in the UHI effect due to increases in density (Figure 7.4).

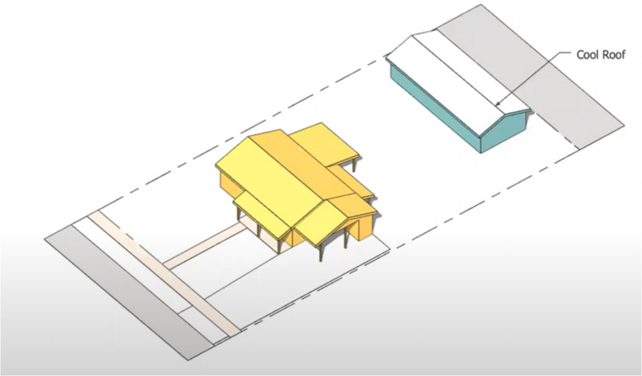


Figure 7.4. Illustration of the cool roof requirement for the City of Tucson's accessory dwelling unit ordinance (City of Tucson)

In higher-density urban areas, development regulations should also take into account provisions for shaded public spaces and ventilation so that large blocks do not prevent airflow. Development regulations can also require sites to take solar orientation into account to minimize building exposure to hot south- and east-facing directions and increase natural shading for pedestrians provided by buildings.

Streetscape Design Guidelines

Streetscape design guidelines that prioritize heat mitigation in commercial areas heavily used by pedestrians can be a critical component of heat planning.

Such documents typically already contain many elements critical for protecting the thermal comfort of pedestrians. These include appropriate trees that provide shade and are well suited to urban areas; increased vegetation, such as green stormwater infrastructure or appropriate vegetation in planters; provisions for built shade, such as awnings or stand-alone shade structures; transit stops that offer shade at the hottest times of the day; seating opportunities that use materials and colors that decrease surface temperatures; cool pavement coatings to reduce road surface temperatures; and provisions to ensure that building waste heat from mechanical systems is directed away from pedestrian and public space areas.

Building Codes

While local building codes usually follow state-adopted or national standards, they should be reviewed to ensure they are sufficient and appropriate for regional climate change projections.

In general, any additional gains in the energy efficiency of buildings reduce greenhouse gas emissions and contributions to climate change while also reducing waste heat and contributing to the local UHI effect. Increases in efficiency of building mechanical systems, such as heating, ventilation, and air conditioning (HVAC), also reduce greenhouse gas emissions and waste heat. Building codes should be updated to allow newer technologies, such as cool roofs and walls and green roofs and walls, as appropriate for the local climate and geography.

Homeowners Associations and Covenants, Conditions, and Restrictions

Homeowners associations (HOAs) are frequently created for new residential subdivisions and typically establish their own rules and regulations for property owners. Communities may also have covenants, conditions, and restrictions (CC&Rs), which are private property requirements that can specify everything from landscape requirements to permissible paint colors for homes.

Planners should engage with HOAs to encourage them to create rules and regulations and CC&Rs that balance aesthetics with heat mitigation strategies. Potential strategies include ensuring that adequate trees are provided for shading along roadways and open spaces and that CC&R paint color schemes and roof material requirements are appropriate for the climate and encourage lighter, more reflective colors where appropriate.

Existing HOA rules and regulations and CC&Rs should not be ignored either. In many communities, subdivisions subject to these rules make up a significant percentage of a jurisdiction's physical area and thus CC&Rs control a large proportion of an urban area's landscaping. Planners can work with existing HOAs on education for heat mitigation and make updated plant lists and color schemes available to consider adopting or modifying for their use.

PUBLIC INVESTMENTS

Some communities are already beginning to consider heat mitigation in public investments, such as capital improvement programs, public bond programs, and investments in public infrastructure within the right-of-way. Heat can be explicitly added as a criterion for evaluating and prioritizing projects or programs that use public investments. This is especially relevant for public investments in parks, open space, and trails; flood management infrastructure; transportation and transit infrastructure; and public buildings, as discussed below.

Planners could include heat mitigation as a selection criterion for public-private partnerships as well, while tax increment finance (TIF) programs could be set up to include heat mitigation and management as specified goals. Finally, economic development incentives that involve land-use changes or new development should also include heat mitigation in the community's larger suite of goals. For all of these heat-related investments, it is critical to also consider the long-term maintenance and operating costs (Holzheimer 2010).

Parks, Open Space, and Connections

Parks, open spaces, and connections such as trails or greenways often make up a substantial portion of a community's vegetated open space. They are often more frequently located in higher-income areas, however, and are therefore less accessible to lower-income and marginalized communities. New parks, open space, and connections should be equitably distributed, which often means prioritizing new investments in historically underserved areas. Vegetation typically needs to be maintained (e.g., pruned, mowed, watered, etc.), and these costs should be factored into investment plans.

For both new and existing parks, several amenities should be considered related to heat. The cooling effect of

Figure 7.5. Shade structure over playground equipment at Sunset Park in Las Vegas, Nevada (Clark County)

parks often extends into surrounding neighborhoods, so in some cases, additional investments in vegetation may be warranted. Shade for community members can be further enhanced with tree canopy or built shade structures. Playground equipment should be shaded to ensure safe temperatures for younger children (Figure 7.5). Finally, splashpads and misters can provide cooling opportunities for families with much less risk and water use than traditional public pools.

Flood Management Infrastructure

Flood management infrastructure includes both traditionally built infrastructure and green stormwater infrastructure.

Research suggests that so far, heat has rarely been a focus for siting green stormwater infrastructure in U.S. cities (Hoover et al. 2021; Meerow 2020), but this represents an opportunity for planners and their communities to improve heat resiliency. While green stormwater infrastructure was first popularized for its flood reduction benefits, it also provides the co-benefit of heat reduction through increased urban greening (Matsler et al. 2021). Areas of communities that are prioritized for green stormwater infrastructure—those with higher amounts of impervious surfaces and often lower-income or marginalized neighborhoods—are typically the same locations where heat mitigation efforts should also be prioritized (Meerow 2019).

Flood management infrastructure should be recognized for heat reduction benefits when the facility design would have a cooling effect. Heat should be explicitly considered in the prioritization of projects, such as through a capital improvement plan (CIP), to ensure that new flood management infrastructure investments are also designed to maximize heat mitigation.

In contrast to green stormwater infrastructure, traditional stormwater infrastructure has the potential to increase heat. This includes large, barren retention or detention ponds and concrete-lined stormwater runoff channels. The potential negative impacts of these traditional stormwater systems on increasing heat should be considered in evaluating and prioritizing potential projects. Unintended urban heat generation can be avoided by considering heat mitigation in the design of new stormwater infrastructure or retrofitting existing infrastructure with additional shading and vegetation where possible.

Transportation and Transit Infrastructure

Transportation infrastructure, such as roads and parking lots, is a major contributor to the UHI effect. Various cool pavement coatings are being piloted and tested in cities to help decrease surface temperatures of the pavement and concrete where possible. These could be integrated into public works manuals or street standards as optional or recommended materials.

"Cool corridors"—multipurpose transportation corridors that prioritize cooler temperatures for pedestrians and bicyclists through cool surfaces, additional vegetation, and increased shade opportunities—should be prioritized in high-use areas. Roadway and parking lot diets, or efforts

Figure 7.6. The City of Los Angeles piloted several varieties of bus stops and related amenities to test their effectiveness in providing shelter, shade, safety, and comfort for users (StreetsLA–STAP)

Figure 7.7. Green roof on the Chicago City Hall, a highly visible example of a public building showcasing heat mitigation (U.S. Department of State)

to reduce pavement surface areas, should be considered when appropriate to further reduce heat.

Transit infrastructure, such as bus, streetcar, and train stops and stations, must be planned for heat as well. Planners should be aware of solar orientation throughout the year and ensure that, particularly in the hottest periods, transit riders have adequate access to shade and drinking water, and that seating options are an appropriate color and material to reduce surface temperatures (Figure 7.6). Additional vegetation and reduction in impervious surfaces around transit stop locations can also help keep transit riders cool. Design manuals for transit stops could include these elements.

In addition to heat-resilient physical transit infrastructure, transit operators should have a plan to be activated during heat warning periods that includes timely public notifications of any changes in operations, heat safety awareness and education material at stops, and—most importantly—reliable transit service, so that transit users are not waiting for excessive periods in extreme heat.

Public Buildings

Public buildings provide a heavily used and visible opportunity for local governments to showcase the best heat mitigation practices. These facilities include municipal offices, town or city halls, libraries, community centers, schools, libraries, recreation and public restroom facilities, and public housing.

Public buildings can be updated to be more energy efficient through updated HVAC systems, cool roofs or walls, green roofs or walls (Figure 7.7, p. 81), or solar panels that produce renewable energy and also reduce building heat gain. The exteriors and spaces around public buildings can also be fitted with additional shade through trees or built shade structures. When appropriate, signage or education materials can be provided to help increase public awareness about the updates and how they increase urban heat resilience.

Many public buildings can also be used as either emergency or summer-long cooling centers or resilience hubs. Community centers and libraries are often well suited for this purpose as they are already heavily used by the public, have staff who are used to assisting the public, and are locations that are already well known to community members. Schools are also often considered temporary shelter locations for emergency situations and may be appropriate when additional capacity is needed for cooling locations during extreme heat events. These public buildings can all be outfitted with emergency backup power to ensure indoor cooling is consistent even in the event of an energy grid disruption.

CONCLUSION

While most planners may not consider themselves heat experts, this chapter has shown that many of the existing processes, plans, and regulatory tools that planners are very familiar with can be used to enhance resilience in the face of the growing threat of urban heat.

Planners frequently engage with other local officials, organizations, and community members to develop a collective vision of the future, and heat risks and mitigation and management strategies should become part of these processes. As discussed earlier in Chapter 4, planners should also make sure that heat mitigation and management strategies are integrated and coordinated across their communities' networks of plans, including comprehensive plans, hazard mitigation plans, climate action plans, and in policy documents, such as design guidelines. Land-use and development regulations and public investments provide particularly important opportunities for planners to contribute to heat mitigation.

Chapter 8 wraps up this report with final recommendations on how planners can advance urban heat resilience and outlines priorities for future evaluation and research that will help inform planning for urban heat resilience.

CHAPTER 8

ADVANCING URBAN HEAT RESILIENCE

As this PAS Report has made clear, both chronic and acute heat risks are increasing. Heat is already the number one weather-related killer in the United States, and heat impacts are projected to increase as temperatures rise. The way communities are planned shapes heat risk, and planners have the responsibility to ensure that their communities are equitably advancing urban heat resilience.

If planners do not address heat, the picture will be grim. New development will continue to increase the urban heat island (UHI) effect and contribute to more greenhouse gas emissions. Community members will adapt by using more air conditioning and potentially opting to drive instead of using active modes of transportation, further increasing waste heat. If chronic heat risk is not addressed as average temperatures rise, and emergency response efforts for extreme heat events remain uncoordinated and do not reach those who need them the most, then heat will strain economic activity, infrastructure, vegetation health, quality of life, and ultimately, public health.

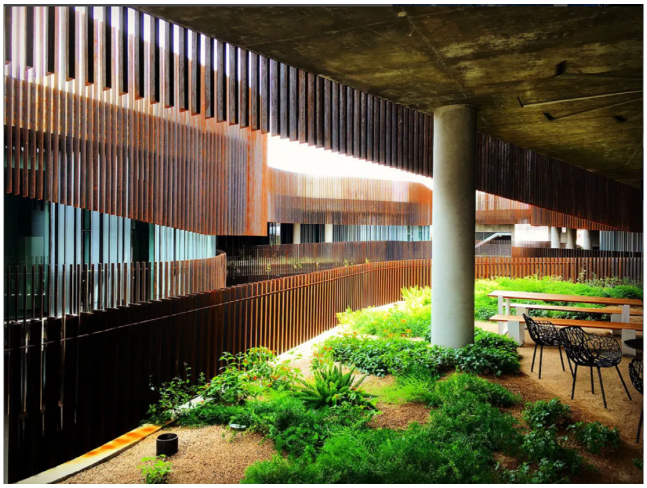


Figure 8.1. Shaded and ventilated outdoor spaces provide cool areas throughout the year at the University of Arizona's ENR2 building, designed to mimic a desert slot canyon (Simmons Buntin)

If planners address increasing heat through the actions outlined in this report, these dire scenarios can be avoided. In a more desirable vision of the future, new development will contribute less to the UHI effect, or even help to mitigate it (Figure 8.1). Public participation for heat planning will be inclusive, so that the strategies selected are appropriate for all community members, particularly those most marginalized. Both chronic heat and acute heat will be addressed, so housing quality, indoor cooling accessibility, and energy affordability are also prioritized. Emergency response efforts will be coordinated so that when extreme heat events occur, efforts are aligned and reach those in need. Impacts of heat to communities will be reduced and avoidable heat-related illnesses and deaths will be prevented.

WHAT WE KNOW

A key challenge for planners in considering urban heat resilience is that heat planning is a relatively new area to the planning profession. With any new planning area comes uncertainties, which can lead to delayed action.

While heat planning may still be unfamiliar to most communities, there is ample information that planners can use as a basis for heat planning today:

- **Climate change.** The climate is changing due to continued greenhouse gas emissions, and a key impact to communities will be the increases in the average temperature and increases in the frequency, duration, and intensity of extreme heat events. Regional and local climate change projections are now widely accessible.

ADDITIONAL URBAN HEAT RESILIENCE RESOURCES

For planners interested in a deeper dive into certain areas of urban heat resilience, there are a wide variety of reports and resources available. Some of these include:

- ***Fourth National Climate Assessment*** (U.S. Global Change Research Program, 2018). As mentioned in Chapter 2, the NCA is a critical resource for local governments with summaries of climate projections and impacts for diverse U.S. regions. The fifth NCA is expected in 2022.
- ***Heat Wave Guide for Cities*** (Red Cross Red Crescent Climate Centre, 2019). This guide provides information on how cities can better manage heat risk and prepare for extreme heat events.
- ***Reducing Urban Heat Islands: Compendium of Strategies*** (U.S. Environmental Protection Agency, 2012). The EPA's guidebook on reducing urban heat islands was one of the first available detailing strategies to reduce the urban heat island effect.
- ***Centering Equity to Address Extreme Heat*** (Urban Institute, 2022). This report provides an overview of heat equity considerations and recommendations for addressing heat equitably.
- ***Killer Heat in the United States*** (Union of Concerned Scientists, 2019). This report provides more information on the health impacts of extreme heat and projections for future extreme heat events in the US.
- ***Too Hot to Work*** (Union of Concerned Scientists, 2021). This report examines how more extreme heat from climate change could affect outdoor workers' health and earnings in the future.
- ***Scorched: Extreme Heat and Real Estate*** (Urban Land Institute, 2019). This report outlines how extreme heat will impact the real estate sector and provides an overview of heat resilience strategies.

- **UHI effect.** The UHI effect, whereby urban areas are hotter than surrounding land, was first observed almost 150 years ago, and the factors that increase the UHI effect are well documented. These include the loss of vegetation, the increase in impervious surfaces, the shape and form of the built environment, material reflectivity, air pollution, and waste heat.
- **Heat impacts.** In addition to heat-related illnesses and death in public health, heat also impacts education, mental health, and quality of life. Outside of public health, heat impacts energy and water use, wildlife and vegetation, infrastructure, and economic activity.
- **Heat vulnerability.** It is well documented that the elderly, those with preexisting health conditions, people experiencing homelessness, marginalized and low-income residents and communities, and all of those who live with systematic inequities have the highest heat vulnerability.
- **Heat mitigation and management strategies.** A variety of heat mitigation strategies have been shown to be effective at reducing heat in the built environment and heat management strategies can address chronic and acute heat risk.

As discussed throughout the report, much of this information is already widely available and accessible to planners. See the sidebar on this page for additional resources useful to planning for urban heat resilience.

WHAT WE DON'T KNOW

While there is some level of uncertainty and a lack of perfect information in all areas of planning, there are some key areas of uncertainty more specific to heat planning:

- **Costs and benefits of strategies.** The costs and benefits of heat mitigation and management strategies are often difficult to quantify.
- **Heat measurements.** Heat is notoriously difficult to measure, depending on whether planners are referring to land surface temperature used for UHI effect maps, real-time ambient air temperature, or thermal comfort through indices like the wet bulb globe temperature (WBGT).
- **Reliable heat-health data.** Although there are efforts to improve heat-health reporting, data varies across states and local public health departments. Heat-related

URBAN HEAT-RELATED NETWORKS

Several heat-related networks aim to connect practitioners and researchers interested in better understanding and addressing extreme heat. Some of these include:

- **Extreme Heat Network.** An interdisciplinary community of research and practice on the causes, impacts, and strategies to increase resilience to extreme heat hosted by the University of Arizona.
- **Heat Stress Network.** A network hosted by Public Citizen that advocates for and provides resources to improve worker heat safety.
- **National Integrated Heat Health Information System.** NIHHIS is a federal interagency effort jointly developed by the Centers for Disease Control and Prevention (CDC) and the National Oceanic and Atmospheric Administration (NOAA).
- **Global Heat Health Information Network.** GHHIN is an independent, voluntary, and member-driven forum of scientists, practitioners, and policy makers focused on improving capacity to protect populations from the avoidable health risks of extreme heat in our changing climate jointly hosted by the World Health Organization and the World Meteorological Organization.
- **Global Cool Cities Alliance.** GCCA's mission is to promote cooler and healthier cities through connecting companies, researchers, and practitioners interested in cooler materials and technologies.

illnesses and deaths are generally assumed to be undercounted due to this lack of consistency.

These uncertainties may present challenges to planners, and it is important to acknowledge them, but they should not prevent meaningful action in addressing heat risk. Monitoring and evaluating heat planning interventions will help to reduce these uncertainties moving forward, so planners should make evaluation a regular part of implementation efforts.

Current development patterns more often than not increase both the UHI effect and greenhouse gas emissions, so planners have a responsibility to begin addressing heat as soon as possible.

PRIORITY AREAS FOR EVALUATION AND RESEARCH

As heat increasingly becomes a topic that more communities begin to plan for, it is critical that the processes and strategies used to address heat continue to be assessed to understand costs and benefits, uncover tradeoffs, and avoid maladaptations. As noted elsewhere in this report, outcomes of heat, such as heat-related illnesses and deaths, need to be better tracked. An improved understanding of heat planning processes, however, is also crucially important because the planning profession is only just beginning to focus on heat.

Evaluation is a critical component of any planning effort that is often neglected due to lack of funding or staff time. While evaluation of heat planning activities should be included as a component of implementation, planners can also engage with universities and relevant nonprofit organizations to coordinate monitoring efforts. It will be equally important to evaluate nonstructural interventions, such as new heat staff or changes to city operations.

Thorough evaluation of heat planning as it continues to evolve can help inform communities of effective practices that advance urban heat resilience goals. Several heat-specific networks help connect researchers and practitioners and share the latest research findings and opportunities, as listed in the sidebar above.

Several priority areas for future heat planning research include the following:

- **Heat planning and governance roles, processes, and structures.** Heat planning and broader governance, including the actors, processes, and structures that address heat, are emerging at all levels of government across the world to address increasing heat risk. Further studies can help identify effective processes and structures for heat planning and governance, such as whether heat resilience is most effectively coordinated through a chief heat officer or an interdepartmental working group focused on heat. Similarly, how various community plans work together to mitigate and manage heat and whether a specific heat plan is more effective than heat addressed across all plans must also be better understood. The critical role of the planning profession within broader heat governance is also important to document and better articulate.

- **Effectiveness and interactions of heat mitigation and management strategies.** The interactions between heat mitigation and management strategies and more evidence of their costs and benefits should be studied further, as well as potential tradeoffs and maladaptations. Some heat mitigation strategies—for instance, cool roofs—can help reduce the regional UHI effect, decrease indoor air temperatures, and reduce building waste heat, but have little effect on the thermal comfort of pedestrians on the street. The effectiveness of strategies in communities of diverse geographies and sizes should also be evaluated. Allied research disciplines, such as architecture and landscape architecture, and specializations in urban climatology are critical for this area. This evidence will assist planners in identifying appropriate heat strategies for their communities to consider.
- **Heat modelling and mapping for planners**. While most of the research conducted on heat planning is related to modeling and mapping urban heat, research is still needed on what measures of heat are useful for communities to focus on and how to interpret that information to improve decision-making. For instance, UHI maps derived from land surface temperatures have a loose relationship with actual outdoor thermal comfort, but they are still often used for decision-making aimed at improving pedestrian comfort. Real-time ambient air temperature readings may be a closer approximation of outdoor thermal comfort, but those climate sensor networks are rarely accessible or usable to planners and other decision makers. Finally, climate data demonstrating the effectiveness of heat mitigation strategies, whether mapped or collected at specific points, would help planners make a case for continued investments in those areas to their communities.
- **Improving heat-health outcomes.** While heat affects all aspects of communities, arguably its impacts on public health are of greatest concern to the planning profession. The effectiveness of heat mitigation strategies should be assessed not just for reducing outdoor temperatures but also for improving heat-health outcomes, such as reducing heat-related illnesses or heat-related deaths. Likewise, how well cooling center or resilience hub accessibility decreases heat deaths during a heat wave is important to establish. Planners should consider partnering with public health and heat-health researchers, as well as local public health departments, in this area.

Researchers interested in generating usable knowledge for planners and other local decision makers should explore these research areas in partnership with planners and the communities they serve.

A CALL TO ACTION

Heat is already a deadly hazard, and heat risks to public health, infrastructure, economies, and ecosystems are increasing for communities across the world—not just those that are already familiar with extreme temperatures.

Communities everywhere, including those in historically cooler climates, must therefore prepare for increases in average temperatures and extreme heat events beyond their past experiences. This means actively building urban heat resilience, or the ability of urban systems to maintain or rapidly return to desired functions in the face of chronic and acute heat risks, to adapt to changing urban climates, and to quickly transform systems that limit current or future capacity to adapt to extreme heat.

Now is the time for the planning profession to step up and take a leading role in coordinating communities' efforts to proactively build urban heat resilience. Why should planners be the ones to lead on heat? First, professional planners are committed to fostering equitable community health and safety, including in the context of climate change. Second, planners' work already focuses on both shaping the built environment and preparing for hazards. Third, planners are experienced in engaging communities and coordinating with different disciplines and sectors. All of these are critical elements for equitably and holistically addressing urban heat resilience.

As outlined in this report, urban heat resilience planning requires setting clear goals and metrics, compiling a comprehensive information base on community heat risks, planning and implementing both heat mitigation and management strategies that are robust to future uncertainties through participatory processes, integrating these strategies across community planning efforts, and monitoring and evaluating their effectiveness over time.

The work that many planners do already shapes their communities' urban heat resilience, from land-use regulations to urban greening. These connections need to be explicitly recognized to bring this often-invisible hazard into focus. Planners can coordinate with other disciplines critical to addressing heat—including public health professionals, architects, landscape architects, real estate developers, emergency managers, hazard mitigation planners, and utility companies—to advance equitable urban heat resilience. These collaborative efforts are critical as we plan for a more equitable and sustainable future in an increasingly urban and warming world.

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Finally, thank you to the planners and all others who work to make communities more equitable and resilient. We hope this report helps advance your efforts to improve urban heat resilience.

DIVE DEEPER

with these related PAS resources.

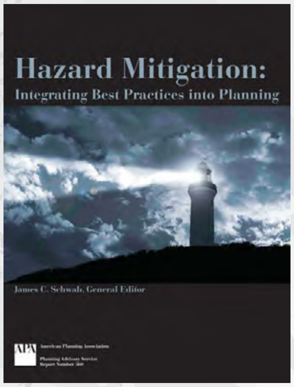

PAS QUICKNOTES

Urban Heat Resilience

Urban Heat Resilience

(PAS QuickNotes 95)

Heat is the deadliest U.S. weather-related hazard, posing a growing and inequitable threat to human health, infrastructure, and economic systems. Share this two-page brief on how planners can enhance urban heat resilience for their communities with heat mitigation and management strategies.


Hazard Mitigation:

Integrating Best Practices into Planning

James C. Schwab, General Editor

Hazard Mitigation: Integrating Best Practices into Planning

(PAS Report 560)

Every year, communities face natural hazards that threaten lives and cause millions of dollars in property damage. Well-crafted plans, policies, and land-use regulations can help mitigate those impacts. Read this report for guidance on integrating hazard mitigation into local planning processes.

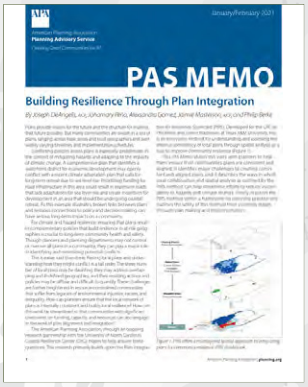

PAS REPORT 596

PLANNING FOR INFRASTRUCTURE RESILIENCE

Planning for Infrastructure Resilience

(PAS Report 596)

Climate change is causing more frequent and intense storm events and rising sea levels, putting communities at higher risk of flooding and cascading impacts. Read this report for guidance on addressing new climate realities in planning processes to create more resilient infrastructure.


PAS MEMO

Building Resilience Through Plan Integration

Building Resilience Through Plan Integration

(PAS Memo)

Plans provide structure for creating an envisioned future — but if a community's network of plans is not coordinated, policies within these plans could be in conflict. Read this article to learn how planners can use the Plan Integration for Resilience Scorecard (PIRS) to improve plan consistency and reduce vulnerability to hazards and climate change.

APA members and PAS subscribers get full access to the PAS digital toolbox. Learn more at **planning.org/pas**.

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