CONNECTED COMMUNITIES:

Incorporating New Technologies into Extreme Heat Plans

Connected Communities: Technology and Extreme Heat

CONTENTS

INTRODUCTION

Across the United States, cities are recording record temperatures and deaths due to extreme heat. Daytime temperatures can be as much as seven degrees Fahrenheit higher than surrounding rural areas due to the "heat island" effect. Extreme temperatures in urban environments are slow to subside after sundown as concrete and other materials can hold heat well past sunset - maintaining unhealthy conditions into evening and overnight hours. Physical infrastructure, such as buildings and roads, absorb and re-emit the sun's heat more than natural landscapes, such as forests and bodies of water. In urban areas, where heat-absorbing structures are highly concentrated, and vegetation is limited; "islands" of higher temperatures develop relative to outlying areas. This extreme heat has significant negative repercussions to the health and safety of our communities, as well as our nation's critical infrastructure.

While communities face tremendous challenges from extreme heat, there are ways that technology can be leveraged to help assess and mitigate associated impacts. Historically, advances in technology offer a way to identify the most at-risk areas, issue timely warnings, and offer preventative, adaptation, and mitigation solutions at scale that can help save lives. For example, new technologies, such as artificial intelligence and digital twins, can assist communities with precise targeting of more traditional solutions such as tree planting or use of heat reflecting building materials. This Department of Homeland Security (DHS) guidance is intended to assist planners and decision makers in increasingly connected communities.[1] The background and recommendations included provide a way to evaluate digital technology and data-based solutions to address the risk of extreme heat to develop heat mitigation strategies and plans. This guide recommends a six-step process for developing a plan to leverage emerging technologies to address communities' specific extreme heat challenges.

This work builds on DHS' existing work to provide guidance to State, Local, Territorial, and Tribal (SLTT) government officials on the use of emerging technologies and safeguard connected communities. In light of the increasing threats and hazards from digital technology, DHS published in 2023 guidance entitled *How to Write a Connected Community Strategy* which provides guidance to SLTT officials driving community digital transformation.[2] In addition, the Cybersecurity and Infrastructure Security Agency (CISA) has also produced guidance on the cybersecurity of connected technologies[3] which should be considered when implementing any technology solution.

BACKGROUND

The Growth of Connected Communities

More than eight billion people live on Earth and more than half live in urban areas. Currently, 83% of US residents live in some type of urban environment. That number is expected to grow to 89% by 2050. As urbanization accelerates, the demand for infrastructure will also increase. In response, community planners are rapidly turning to digital technology to meet the growing demands and challenges of urban life.

Connected communities solve municipal challenges by deploying technologies such as Cyber-Physical Systems and Internet of Things (IoT) devices to improve the quality of life for their residents. These and other similar technologies can involve cyber-networking devices and other supporting systems working with physical infrastructure. These technologies and the opportunities they provide range from the common, such as smart traffic signal lights to reduce traffic, to the cutting edge, such as a digital simulation of every tree in New York City. Connected community technology can apply to operational situations, as when transportation systems are digitized to foster innovative and diverse modes of transportation. It can also apply to governance, as when a town creates new applications for residents to report issues, access resources, or view and participate virtually in council meetings. When applied throughout a city, technologies such as these could expand and improve services, promote economic growth, enhance quality of life, and address a number of other challenges communities face, including mitigating the effects of extreme heat.

As discussed in the DHS *How to Write a Connected Community Strategy* municipal leaders should develop a strategy and vision of their connected community that optimizes benefits to residents before embracing these evolving technologies. Readers of this guide are encouraged to review that guide[4] to assist in the development a comprehensive plan for the incorporation of connected community technologies. Within the guide, municipal leaders will find best practice advice from experts nationwide to help them navigate a municipal digital transformation.

Defining Extreme Heat

Extreme heat is one of the deadliest weather impacts in the U.S. Between 1970-2022, the continental U.S., including Alaska, has warmed about 60% faster than the entire planet.[5] This increase in temperature has led to an increase in heat-related health impacts in the U.S. Between 2004 and 2018, extreme heat was estimated to be responsible for more than 700 deaths per year - some estimates even put heat-related mortality closer to 1,300 deaths annually.[6] Higher temperatures are associated with adverse pregnancy and birth outcomes; mental health impacts; and increased emergency room visits and hospitalizations related to cardiovascular disease, diabetes, electrolyte imbalance, renal failure, and negative respiratory reactions. These temperatures are also related to higher rates of aggressive behavior in both humans and wildlife, leading to additional unknown threats to communities facing faster rates of warming.

Historic community planning and development has resulted in areas that are more susceptible to extreme heat, resulting in highly variable impacts depending upon location and demographics. Deaths and other effects from extreme heat often impact people and parts of society unequally. Heat-related health impacts are greatest among children, adults over age 65, those with disabilities, people with mental health or substance-use disorders, and those who are pregnant, lack access to cooling, or engage in outdoor labor and activities.[7] Communities with low wealth and those experiencing homelessness will also be disproportionately exposed to heat.

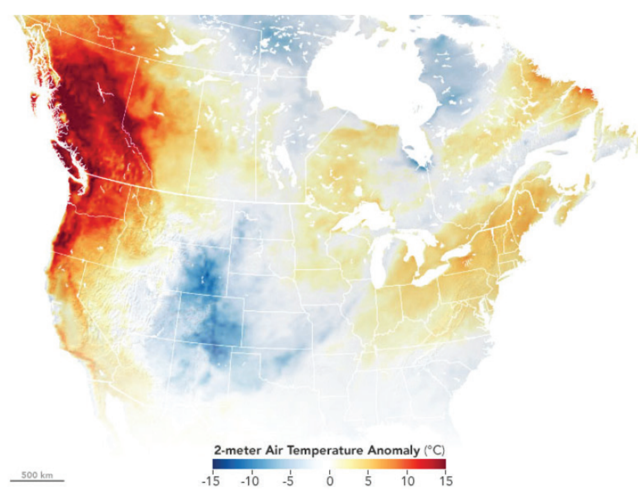
The impacts of extreme heat are more severe if high temperatures persist for several days. In recent decades, multiday heatwaves have become hotter and more frequent, cover larger regions, and are longer lasting. Across 50 large U.S. cities, the average number of heatwaves per year has doubled since the 1980s, and the length of the annual heatwave season has increased from about 40 days to about 70 days.[8]

As global average temperatures continue to warm, the risk of record-breaking heat events will continue to increase for peak temperatures, length of time, and coverage area.

Heat Dome Effects

During an extreme heat event, heat domes can create more severe conditions and threaten safety. A heat dome is a weather phenomenon that is caused when the atmosphere traps hot air at the Earth's surface, as if bounded by a lid or cap, under which high-pressure conditions force the hot air to remain stationary for days or weeks. Heat domes are expected to increase in coming decades due to pattern shifts in the upper atmosphere aggravated by the uneven distribution of heating across the globe.

In the summer of 2021, the Northwest experienced record-breaking high temperatures from late June through mid-July. That single heat dome event caused over 250 deaths in the U.S. and more than 400 in Canada.[9] That event also put stress on local infrastructure including hospitals, with hundreds of heat-related emergency visits reported for Oregon, Idaho, Washington, and Alaska. Elderly people, homeless people, people who work outside, and people who do not have access to air conditioning were especially vulnerable. In addition to health and safety impacts, physical infrastructure was affected. In Washington



A map of the magnitude of temperature anomalies–temperature that was higher or lower than the long-term average-that occurred during the 2021 heat dome.

state, the heat caused sections of Interstate-5 and State Route 162 to buckle, causing some lanes to be closed. In Portland, OR, the heat exceeded the design limits of the TriMet MAX system, causing train power lines to sag and subsequently shutting down trains.

Extreme Heat and the Urban Heat Island Effect

A heat island refers to certain areas of cities which tend to get much warmer than their surrounding landscapes, particularly during the summer. This temperature difference can lead to mid-afternoon temperatures that are 15 to 20 degrees Fahrenheit warmer than the surrounding vegetated area.[10] Heat islands can often be the deadliest area of a city during an extreme heat event. According to the EPA, there are five factors that contribute to the sustained high-level temperatures that cause a heat island:[11]

- **Reduced Natural Landscapes:** Urbanization tends to diminish natural landscapes in service of manmade infrastructure. Trees, bodies of water, and other natural features play an important role in cooling local areas. In contrast, the prevalence of hard, arid surfaces like roofs, pavements, and buildings in cities contributes to elevated temperatures contributing to the urban heat island effect.

- **Urban Material Properties:** Traditional urban structures and construction materials absorb more of the sun's heat and radiate more energy compared to natural surfaces and vegetation. Urban construction materials, once heated, continue to release heat at slower rates than surfaces made from natural materials. Consequently, urban structures intensify the urban heat island effect throughout the day and cause it to persist well after sunset.

- **Urban Geometry:** The arrangement and dimensions of buildings in urban settings also influence the urban heat island effect. Buildings in densely populated areas can become significant sources of heat raising temperatures in localized areas. Furthermore, the arrangements of buildings can create an "urban canyon" of narrow streets and tall buildings, hindering natural flow of cooling air.

- **Heat Generated from Human Activities:** Various human activities such as vehicle emissions, industrial process, and energy production emit heat. These activities, multiplied by an urban setting, can exacerbate local heat island effects.

- **Weather and Geography:** Local weather conditions and geography can worsen or lessen the urban heat island effect. Clear weather conditions can maximize the amount of solar radiation reaching surfaces, while gusty winds and cloud cover can reduce the impact. Geographic features and infrastructure design can impact heat islands by blocking winds or inducing wind patterns and trapping heat and humidity with inversion layers.

Planning for Extreme Heat

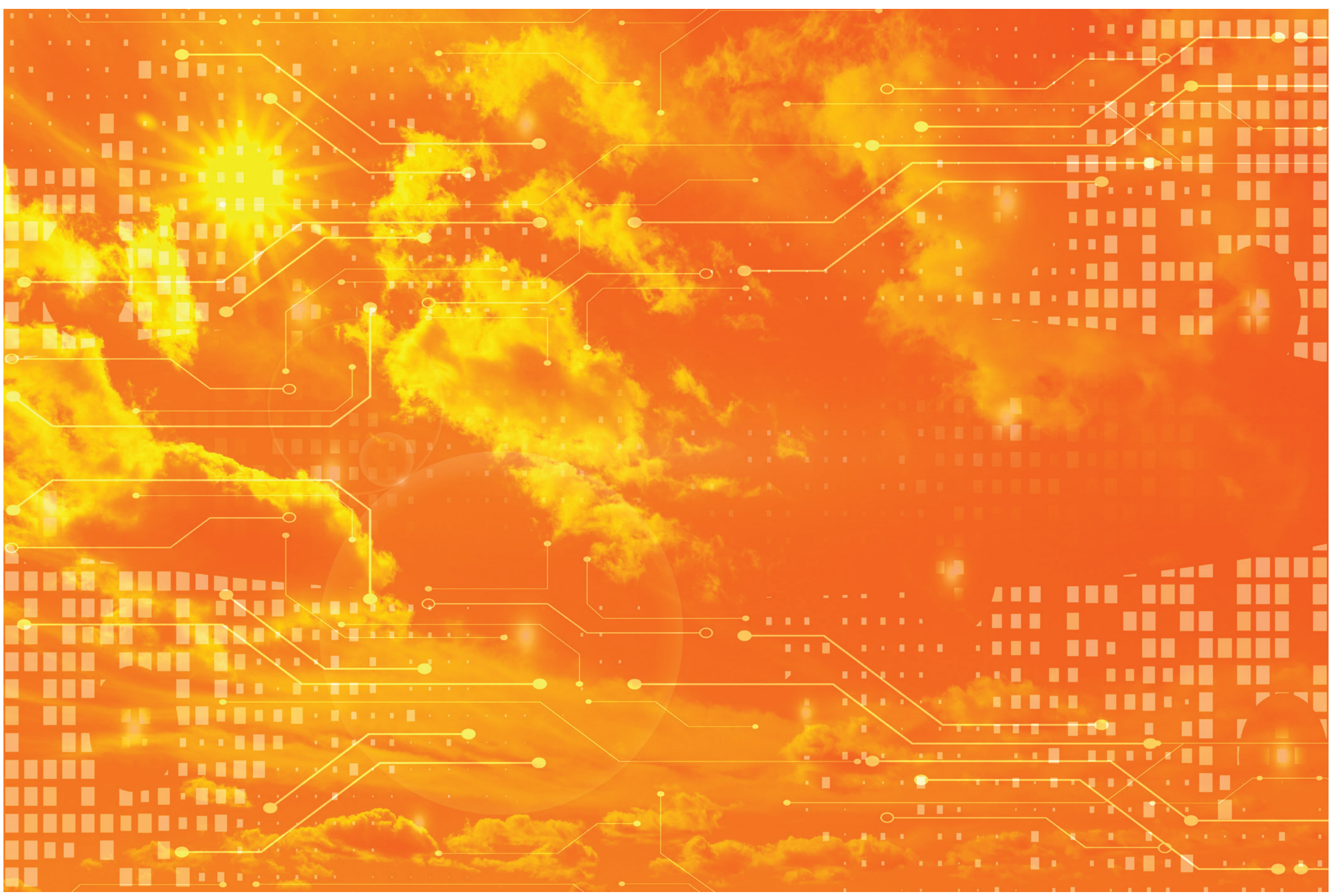
SLTT Governments are developing adaptation plans to address the impacts of extreme heat. These plans may focus solely on extreme heat or address extreme heat as one risk alongside other natural hazards, such as floods or droughts. In other instances, a variety of officials within a community such as public health staff, emergency managers, parks and recreation offices, flood management officials, and transportation planners may also directly or indirectly address extreme heat risks individually in their more narrowly focused plans. Regardless of the scope, implementation of these extreme heat plans across the various governmental bodies address two broad issues: heat mitigation and heat management.

- Heat mitigation strategies are generally related to planning and design, such as through land-use planning, urban design, urban greening, and waste heat reduction.[12] These strategies include efforts around urban development patterns, building orientation and shade structures, urban forestry, stormwater infrastructure, and building energy efficiency, among other efforts.

- Heat management strategies are generally related to public health and emergency management and emergency preparedness.[13] These strategies include resilient energy infrastructure and availability for indoor cooling, reducing personal exposure, public awareness campaigns, early warning systems, and cooling centers, among other efforts.

Heat mitigation and management strategies often use traditional solutions such as shade requirements, early warning systems, cooling centers, and more. However, the challenge continues and there are still deaths from extreme heat events as temperatures and severity evolve.

To address the continued challenges from extreme heat events, SLTT government and other community planners are beginning to consider leveraging or incorporating technology solutions within their new or existing heat plans to meet current and new challenges. Many of the technologies that define connected communities, such as smart traffic management, digital twins, next generation emergency response, and energy efficient buildings, can be used to help mitigate heat and be incorporated in a community's heat plan. By doing this, planners can leverage the benefits of a connected community for their residents and simultaneously use the technologies as a multiplier effect for their existing and future heat management plans. As discussed in the next section, however, efforts to leverage new technologies to mitigate and manage extreme heat can be more effective when extreme heat and technology plans are better integrated and viewed together as part of a larger connected community approach.



RECOMMENDATION

Community technology plans and heat (or other climate related) plans are often created and implemented separately without incorporating the features of each other well. As communities look to the future, they should consider integrating technology as a part of their heat plans. Based on our review of existing community heat and technology plans, communities looking to better integrate digital technology into their planning for future extreme heat conditions should review and consider implementing the following six steps:

1. Establish a baseline of heat risks and harms.
2. Establish extreme heat plan or other related weather adaptation plans.
3. Incorporate connected community technologies and other innovations into the heat plan.
4. Select funding models for heat mitigation and adaptation strategies.
5. Eliminate barriers between municipal executives.
6. Evaluate the implementation and efficacy of heat plan and other related weather plans on a regular basis.

STEP 1: Establish Baseline of Heat Risks and Harms

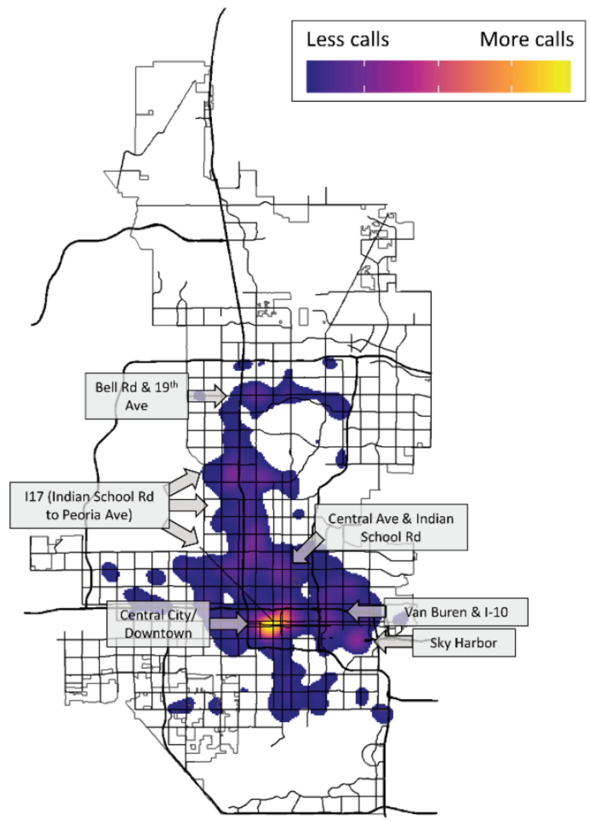
Community leaders likely understand their community needs and routinely prepare for a variety of hazards. This increasingly involves developing a heat plan or launching heat-related projects. Such efforts require assessing established laws, policies, plans, activities, and jurisdictions as they relate to extreme heat mitigations and response. The goal in developing a baseline of heat risks and associated harms is to identify the community's specific drivers of extreme heat, its impacts across their population and infrastructure, and any previous actions aimed at addressing extreme heat.

For example, *The City of Phoenix Summer 2023 Heat Response Plan* prefaces the actual plan with a summary of heat related data points for Phoenix from 2022. City of Phoenix planners collected and summarized data over 10-day stretches in which the average temperature was above the climatological average. The plan also summarized heat-associated mortality statistics from the Maricopa County Department of Public Health as well as heat-related illness response statistics from the Phoenix Fire Department between April and September 2022. All the data collected and analyzed was used to inform *The City of Phoenix Summer 2023 Heat Response Plan*.

The 2023 Phoenix Plan is just one analytical example of how a community can develop a baseline before developing a heat plan. Generally, planners should consider the following variables when assessing their communities:

- Municipal services and utilities such as public safety, water, and sanitation.
- Physical infrastructure such as buildings and service-supporting infrastructure.
- Physical security and cybersecurity of digital infrastructure such as IT assets and telecommunications networks.
- Design of new technology and interdependencies
- Jurisdictions with authority over utilities, services, infrastructure, and land.
- Stakeholders, especially community residents.
- Demographics and population distributions.
- Existing policies, rules, regulations, and laws and all levels of government.
- Current and forecasted budgets and funding.
- Community leadership priorities.
- Relevant datasets provided by Federal Government agencies and municipal service providers.

Understanding the impact of extreme heat on a community is an exercise in collecting data, engaging both residents and officials, and developing insights that help planners take action. In addition to understanding the nuances of a community, planners also need raw data about the heat of their jurisdiction. Satellite temperature data is the most cost effective first step in identifying the areas most affected by extreme heat. Identifying types of vegetation cover or estimating heat vulnerability due to demographic characteristics can be coupled with satellites to provide greater focus areas for mitigation planning. Efforts such as the National Integrated Heat Health Information System's (NIHHIS) Urban Heat Island Mapping Campaign combine ground-based measurements of air temperature with satellite-derived land surface temperature to gain a better understanding of heat impacts on humans.[14] This data can then be used to adopt targeted heat mitigation and management strategies and even deploy emerging and innovative technologies to address extreme heat.



Community leaders may need to collaborate with relevant stakeholders, including local government agencies, emergency managers, health departments, and community organizations as they engage with residents to gather firsthand insights to further understand community needs. Ultimately, the goal of this analysis is informed planning and decision-making. As resources are finite and the global supply chain faces greater uncertainties, localized data and improved analysis will provide greater validity to apply resources most effectively and equitably, ensuring a robust heat plan.

STEP 2: Establish Extreme Heat Plan

Upon completing step one, planners will be ready to develop extreme heat plans targeted to their communities. An extreme heat plan is a comprehensive strategy designed to mitigate the negative impacts of extreme heat events within a community. Heat plans must also integrate with existing planning around other hazard mitigation and disaster preparedness that enhance resilience. To understand and address short- and long-term impacts, two key components of an extreme heat should include:

- **Forecasting and Monitoring:** Reliable weather forecasts and comprehensive temperature monitoring allow local officials to issue timely heat alerts, warn residents, and prepare responses.
- **Education and Awareness:** Community leaders must raise awareness about heat risks, symptoms of heat-related illnesses, and available resources to allow residents to plan accordingly.

Developing an extreme heat plan is crucial for communities to safeguard public health. By planning early, communities are better prepared to respond to extreme heat events and protect vulnerable populations from heat-related illnesses and fatalities. Extreme heat plans help community leaders make critical municipal services more resilient to extreme heat events. For example, deliberate use of resilient materials and energy efficiency measures reduce disruptions to city services and stress on electricity systems during heatwaves. Furthermore, extreme heat plans promote long-term thinking. A robust extreme heat strategy will include measures to mitigate some of the heat island effect and ensure sustained resilience against future extreme heat events.

The *2022 Miami-Dade County Extreme Heat Action Plan*[15] provides an illustrative example of how analysis from Step 1 was used to inform a robust extreme heat plan. The County contracted with researchers from Florida State University to identify risk factors for heat-related hospitalizations. The researchers identified a link between poverty and heat-related illness as well as county specific exacerbating circumstances that contributed to that linkage. Miami-Dade County then used that research to develop guiding principles that informed the County's overall heat plan.

STEP 3: Incorporate Connected Community Technologies

Once planners have a good understanding of their situation and heat challenges, they can look at how to best leverage technology and innovations to help address those challenges. As it relates to extreme heat – digital technology can be broadly organized into four categories:

- Technology to support analysis and heat monitoring
- Technology to mitigate extreme heat
- Technology to support extreme heat incident response
- Technology to inform and support the use of non-digital innovations, such as reflective paint or modern building materials

Below are examples of how municipalities used connected community technologies within these categories. Planners are encouraged to consider how these and similar technologies can apply to their own jurisdictions.

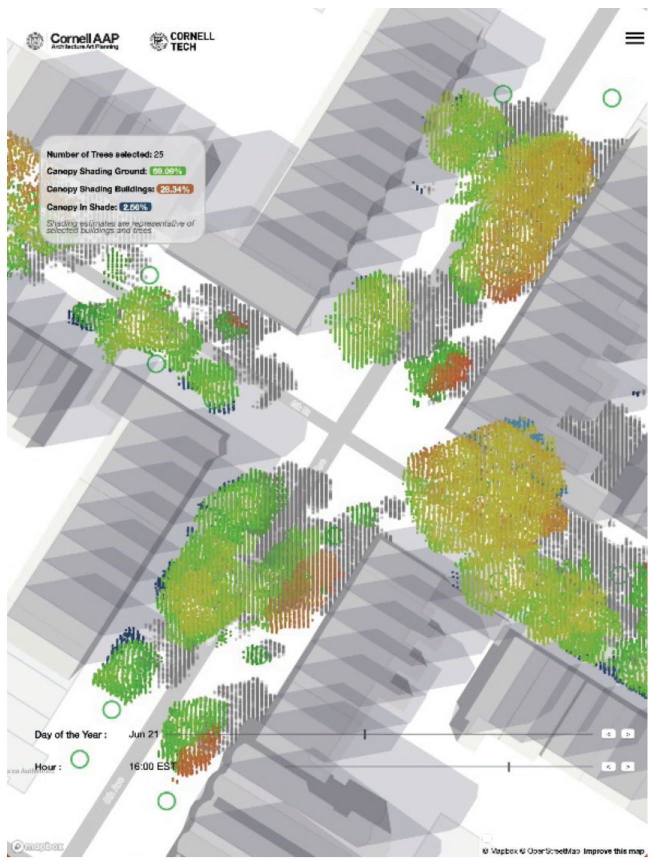
Technology to Support Analysis and Heat Monitoring

A variety of advanced IoT sensors can be deployed across cities to gather high-resolution data that could be used to map and monitor disasters and weather phenomena like extreme heat. In some cases, thousands of sensors have been deployed on stationary objects, such as streetlights and buildings, or mounted on public vehicles, such as buses or police cars. Sensors can monitor a variety of environmental data points such as temperature, humidity, and wind. The information collected can provide a more detailed understanding of specific locations' conditions, which can vary widely, especially when compared to a regional weather forecast. City planners and residents can then use this data to best use limited resources and adapt to extreme heat conditions.

Chicago's "Array of Things" is an excellent example of a municipality using sensors to monitor heat and other environmental factors on a micro level.[16] The Array of Things (AoT) is an urban measurement project consisting of a network of devices installed around Chicago to collect data on the city's environment, infrastructure, and activity. The 130 devices collect environmental data such as temperature, humidity, and air quality pollutant measurements, such as carbon monoxide and ozone levels. The data is used to provide free high-resolution environmental information to the public: residents, organizations, researchers, engineers, and scientists. AoT data has also been used to study the safety of rail crossings, monitor crosswalk usage, detect flooding, and assess public health impacts of air pollution.

With all the data collected from sensors, municipalities can create digital twins. Digital twins are one type of advanced modeling technology that takes advantage of big data analytics and machine learning to create digital models of structures, like vehicles or buildings, that mirror those in the real world. These "twins" can then be manipulated and employed to study the effect of proposed changes – like where and how much of a natural infrastructure solution can be applied to reduce extreme heat impacts." More importantly – digital twins are not static and can be interactive, allowing a user to simulate how multiple variables might impact a structure or location represented by the twin in real time.

In the case of extreme heat, a digital twin could show how the temperature of a building or street changes throughout the day and responds to variables like shade, new construction, paint, and more. Municipalities can use digital twins to track the myriad of variables that impact the urban heat island effect, deploying resources where they can be most effective.



One example of a digital twin used to mitigate extreme heat is the Tree Folio program in New York.[17] Tree Folio NYC, initiated by Cornell Tech, serves as a digital representation of New York City's tree canopy and the shade provided by those trees. The Tree Folio program aims to better understand and quantify the local impact of urban trees. It achieves this by extracting 3D models of every tree in NYC from publicly available, high-resolution, light detection and ranging (LiDAR) scans. The tool can analyze variables such as street orientation, street width, building height, and tree coverage. By doing so, Tree Folio NYC quantifies the amount and quality of shade provided by each tree. This information is crucial for assessing the cooling benefits and overall well-being of urban spaces. The goal of Tree Folio NYC is to develop strategies responsive to local needs. By understanding the impact of trees on shading and climate, it contributes to strategic tree planting, mitigating the effects of a future extreme heat event in the city.

Technology to Mitigate Extreme Heat

Innovative technologies also play a crucial role in mitigating the adverse effects of extreme heat. Examples include advanced weather forecasting systems, smart grid technologies, and energy-efficient cooling solutions which help protect vulnerable populations, reduce energy consumption, and maintain critical infrastructure. By leveraging these technological advancements, community planners can build more resilience to extreme heat.

One such technical advancement that can make communities more resilient is smart glass. Smart glass contains thin layers of metal oxide. When those layers are exposed to very small amounts of electricity, the ions move between them, thereby adjusting the glass's tint level. Smart glass can switch between clear and opaque based on conditions like temperature or the angle of the sun. In fact, the 2022 Inflation Reduction Act included a 30% smart glass credit, which could facilitate the adoption of the technology in more communities.[18] When used, this technology can be a great resource to regulate the temperature inside a building as well as to reduce the building's thermal impact on the surrounding area.

An illustrative case study on the benefits of smart glass is the Brownsville South Padre Island International Airport.[19] In 2014, Brownsville South Padre Island International Airport (BRO) team aimed to create a modern passenger terminal due to increased demand borne from the construction of a nearby space launch facility. Given BRO's location in southern Texas, extensive sunlight and heat were significant considerations in planning. To mitigate the heat impact, the BRO design team chose to deploy smart glass windows for over 13,000 square feet of glass. These smart windows automatically tint in response to sunlight, keeping the terminal cool and reducing glare, even during scorching outdoor temperatures (near 100°F). A survey conducted at the airport compared experiences of 160 respondents and found that they were two to three times more satisfied with thermal comfort, daylight, and glare control when the smart glass was active.[20] The BRO case is just one example of how smart glass can be used to reduce the urban heat island effect.

Other technological advancement planners should consider in their efforts to mitigate heat, involve deploying technologies that address some of the causes of heat. For example, traffic congestion is a significant contributor to the urban heat island effect – therefore, any technology or process that reduces traffic can have a secondary impact of reducing local temperatures.

Providing sufficient parking for residents and visitors is a perpetual challenge known to most communities. Intelligent parking guidance systems are designed to streamline the process of finding parking for drivers in congested areas. These systems make use of sensors, cameras, data analytics, and networked communications to provide real-time information about parking availability. The Houston Parking Guidance System serves as a prime example of this phenomenon. By providing real-time information on available parking spaces, the system helps minimize traffic congestion in nearby areas. Reducing traffic congestion in turn reduces the amount of heat and emissions from idling vehicles, contributing to the urban heat island effect. In short – fewer cars searching for parking means fewer combustion engines producing heat, cleaner air, and reduced local temperatures.[21]

Another similar tool municipalities can consider is a smart traffic management system. Smart traffic management systems leverage advanced technologies to enhance the efficiency, safety, and sustainability of urban transportation networks. These systems integrate real-time data from sensors, cameras, and connected devices to optimize traffic flow, reduce congestion, and improve overall mobility. Key features include adaptive traffic signals, dynamic lane management, enhanced public transportation, predictive analytics, and intelligent routing. By intelligently managing traffic, these systems contribute to smoother commutes, reduced emissions, and improved urban living.

The "World's Smartest Intersection" in Detroit is a prominent example of a smart traffic management system. The City of Detroit, in collaboration with a digital traffic management company, unveiled The World's Smartest Intersection in 2018.[22] The technology integrates a system of sensors, networked cameras, and connected traffic signals deployed over 40% of intersections in Detroit. The system generates real-time data that can be used to optimize traffic flows by dynamically adjusting traffic signal timing to manage the flow of traffic. According to Detroit's Head of Traffic Operations, the system has reduced vehicular travel times by 30%. This reduction in vehicle travel times means less vehicles idling, which in turn can lower localized temperatures that contribute to heat islands.

Technology to Support Extreme Heat Incident Response

Even with planning and mitigation strategies, municipalities will still need to be prepared to respond effectively to extreme heat events. "Response" in an extreme heat emergency is typically conducted by emergency management services. A core connected community tool for extreme heat incident response is the Next-Generation 911 call center (NG911). Currently used by many states and communities across the U.S., NG911 represents a significant leap forward in emergency communication systems. Unlike the legacy analog 911 infrastructure, NG911 operates on a digital, internet protocol (IP)-based system.

Unlike traditional, landline-based call centers, NG911 is capable of handling voice calls, text messages, voice-to-text, photos, and videos – allowing the public to share more information with responders in multiple ways. NG911 also facilitates faster response rates by emergency responders by increasing the volume a call center can receive and transferring calls automatically to the appropriate call center based on location. Additionally, NG911's digital format is more reliable and flexible than traditional landline systems, adapting to modern communication trends.

NG911 is a critical emergency response system, particularly in the context of extreme heat. In extreme heat situations, callers may be able to text pictures to provide extra information to first responders, such as burns due to overheating materials. Since NG911 accommodates multiple modes of communication, this ensures that critical information reaches responders supplementing traditional voice calls. NG911 also leverages location-based routing using advanced GPS data and geographic information systems (GIS). This ensures that emergency calls are routed to the nearest appropriate responders, reducing response times, and improving resource allocation during heat-related emergencies.

For planners considering implementing the NG911 system, CISA has provided a guide filled with resources for the safe and secure implementation of these systems.[23] Planners can also find case studies from California[24] and the City of Manassas, VA[25] and the lessons they learned, (such as need for staffing, an understanding and need for data management strategies, and the need to collaborate with neighboring jurisdictions to,) from their NG911 implementations.

Technology to Inform and Support Non-Digital Innovations

Planners should also consider using information from digital technologies to guide their use of non-digital innovations. Identifying where the urban heat island effect is most prominent through the NIHHIS Mapping Campaign, or via sensors from IoT devices is an important step. But often actual heat mitigation comes from non-digital solutions. Emerging advances in manufacturing, chemistry, and biotechnology offer novel approaches to mitigating urban heat island effects. New technologies can be deployed to both directly lessen extreme heat (e.g., new materials that keep surface temperatures lower) and make it easier for policymakers to strategically utilize traditional cooling solutions (e.g., advanced modeling of urban areas).

New urban materials can adjust the albedo[26] – the fraction of light reflected by a surface – of buildings, which can help address extreme heat. Solar reflective coatings have the potential to reduce solar heat gain by about 40%, leading to a corresponding indoor temperature drop of 2-4°C in naturally ventilated buildings or a decrease in cooling energy use in air-conditioned buildings. Widespread adoption of these energy savings in urban environments could potentially lower ambient temperatures by 1°C, thus addressing the urban heat island (UHI) effect more effectively[27]. Similarly, cool roofs, including those that use solar reflective coatings, reduce roof temperature and air conditioning use by reflecting radiation instead of absorbing it.

An example of a community using data to inform deployment of non-digital solutions can be found in The Pacoima, Los Angeles Cool Community Project. Pacoima is a sun-exposed community with an abundance of heat-retaining surfaces (such as streets and public spaces). The Cool Community project used connected community technology to collected data from sensors and a project similar to NIHHIS's to create a detailed heat map of the local area. The city then partnered with a solar reflective paint company to apply solar reflective paints to streets, playgrounds, and parking lots in the hottest areas. Unlike typical urban paints and materials these specialty paints are designed to reflect rather than absorb solar energy. Preliminary data from the projects has shown a 25-50% reduction in the urban heat island effect during peak temperatures and a 13-21% reduction across all day and night hours.[28]

- The above examples of different technologies are not exhaustive but are meant to give planners ideas for how they can plan for and address extreme heat events in their communities. Incorporating these technologies and other innovations into a heat plan can greatly enhance results; however, these technology projects can be complicated and fail when undertaken without due consideration. Therefore, municipalities should consider reviewing DHS's *How to Write a Connected Community Strategy* to jump start municipal innovation planning.

STEP 4: Select Funding Models for Heat Mitigation Strategies

When incorporating technological solutions to address extreme heat, planners should also consider the associated costs and staffing considerations that may dictate the timeline and scale of implementation. While the below list is not exhaustive, there are several considerations for funding infrastructure projects to mitigate extreme heat.

Grant Funding: The federal government has several grant opportunities that can partially or fully fund extreme heat projects. Within DHS, the Federal Emergency Management Agency's (FEMA) Building Resilient Infrastructure and Communities (BRIC) program supports states, local governments, tribes, and territories as they work to reduce their hazard risk.[29] Securing a grant to invest in a variety of mitigation activities with an added focus on infrastructure projects ultimately can help disadvantaged communities; influence nature-based solutions, climate resilience, and adaption; and the adoption of hazard resistant building codes.

Municipal Bonds: Municipal bonds are a type of debt security issued by local, county, and state governments commonly offered to pay for capital expenditures, including the construction of highways, bridges, or schools. Municipal bonds act like loans, with bondholders becoming creditors. In exchange for borrowed capital, bondholders/investors are promised interest on their principal balance—the latter being repaid by the maturity date.

Legislation Changes: The Bipartisan Infrastructure Investment and Jobs Act (IIJA) of 2021 directed unprecedented levels of funding from the Federal government to improve the country's transportation, water, energy, and broadband systems, in addition to addressing a variety of climate needs such as extreme heat. Once a community receives funds, infrastructure projects are ultimately planned, designed, and implemented by state and local leaders.

Public Private Partnerships (PPP): These partnerships are created by contracts wherein the government or a statutory entity is one party and other party is a private sector company. The terms of the contract articulate that infrastructure service(s) must be delivered by the private company upon payment by the public entity. The main goal of PPP construction projects is to combine and involve the capabilities from both the private and public sectors for the mutual benefit.

STEP 5: Eliminate Barriers Between Municipal Executives

Extreme heat is a complex problem requiring a multidisciplinary approach. It is not enough for a community to solely appoint a "Chief Heat Officer" – the heat executive must be connected and integrated with officers responsible for other community services like technology and public health. Extreme heat has a wide range of impacts across civic life, and heat strategies should be developed in conjunction with those already familiar with a community's existing needs and capabilities.

"Silos" refer to individuals or groups who work independently within an organization, often showing reluctance to integrate their efforts with others. These silos can exist at various levels of a community, such as when different departments providing services do not coordinate, or even within teams of a department. Lack of coordination can pose challenges as communities attempt to address extreme heat. Some examples of challenges include:

- Lack of Data and Transparency
- Inefficiencies borne of Cross Department Rivalries
- Privacy and Compliance Concerns
- Failed Delivery of Community Services

Therefore, community planners must strive to eliminate professional silos that may hinder the development and implementation of an extreme heat plan. Eliminating silos in government allows information to flow freely, leading to improved functions, efficiency, and project management. By enabling visibility within the municipality, leadership can make more informed decisions, benefiting the entire community.

Development and implementation of an effective extreme heat plan requires community planners to remove silos whenever possible. Community planners can actively break down silos via serval strategies:

- **Leadership Support:** Silo removal starts at the top. The chief executive of a community – whether that is the mayor, a city manager, or a city council – is responsible for setting a culture of collaboration between departments responsible for community services. Leadership commitment sets the tone for all organizations providing community services.
- **Shared Goals and Metrics:** Align departmental objectives with overarching organizational goals. Establish common performance metrics to ensure everyone works toward the same outcomes.
- **Cross-Functional Teams:** Encourage collaboration by forming cross-functional teams that include representatives from different departments. These teams work together on specific projects, fostering communication and shared goals.
- **Regular Interdepartmental Meetings:** Schedule regular meetings where representatives from various departments discuss challenges, share insights, and coordinate efforts. These forums promote understanding and collaboration.
- **Technology Integration:** Invest in integrated technology platforms that allow seamless data sharing and communication across departments. This reduces duplication of efforts and enhances efficiency.
- Meaningful Engagement: Engage populations that disproportionately experience climate risks and harms in developing solutions. This can help identify issues that cut across departmental portfolios, facilitate cooperation, and improve solutions deployment.

STEP 6: Regularly Evaluate the Implementation and Efficacy of Heat Plans

The job is not over when an energy efficient building is built, or new technology is deployed. Planners will need to continuously evaluate their plans and technology implementations on a regular basis for their effectiveness and review innovation solutions entering the market. In doing so, municipalities can best serve their residents and ensure that each tax dollar is used most effectively.

Evaluations can play a key role in program planning, management, and oversight by providing feedback to decision makers on the achievement of program objectives and other aspects of performance to improve future outcomes and identify lessons learned. Given the wide range of heat plans and their possible interventions against hazards such as extreme heat, organizations should avoid "one-size-fits-all" evaluations and ensure that all evaluations are appropriately tailored in size, scope, timeframe, and other relevant factors. Communities are encouraged to look at guidance such as FEMA's National Resilience Guidance and utilize that (or other tools) to frame their evaluations. This guidance suggests that communities evaluate inputs, processes, outputs, and outcomes. In reviewing these items, planners should consider various evaluation methodologies. For example:

- **Citizen Surveys:** Gathering feedback from residents about their perception of smart city services.
- **Indicator based approach:** Using a set of quantitative indicators across different dimensions to measure performance. For example, tracking reduced emergency response times.
- **Data analytics:** Utilizing data from sensors and other sources to analyze trends and impacts. For example, which building materials have been associated with cooler buildings of less AC use? How effective have new building materials been to reduce heat?
- **Benchmarks:** Has community energy use reduced or are temperature maps revealing improvements in host spot presence? How is your community faring compared to others?

Municipalities should follow the appropriate evaluation standards and leading practices to guide evaluation activities and support evidence-based policymaking. Municipalities should consider using resources found at evidence.gov and the NIST Smart Cities and Communities Framework Series.[30] There, planners can then best evaluate their programs to make certain they continue to serve their constituents in the most effective manner possible.

CONCLUSION

Extreme heat will continue to pose multi-faceted challenges to communities for decades to come. Addressing extreme heat will continue to require a heterogeneous approach that involves public health, urban planning, private industry innovation and community engagement in addition to the implementation of current and emerging technologies. The technologies that underpin connected communities can help planners address the adverse effects of extreme heat while improving the lives of residents when implemented through careful planning and actionable strategies.

While there is no one solution that fits every community, the above steps and examples will advise and guide planners to target, integrate, and improve their heat and technology plans to best address their specific heat challenges and, in doing so, help protect their communities and overall quality of life.

Endnote

1 For the purposes of this guide, we use the term "connected communities," as it is more inclusive than "smart cities." The term "smart city" often emphasizes large metropolitan areas at the exclusion of small towns and rural communities. References to "connected communities" in this guide include mega-cities, rural communities, and all other places where U.S. residents make their homes.

2 https://www.dhs.gov/sites/default/files/2023-10/23_1030_pol_cirr_final-how-to-write-a-connected-community-strategy_508.pdf

3 Connected Communities | Cybersecurity and Infrastructure Security Agency CISA

4 https://www.dhs.gov/publication/how-write-connected-community-strategy

5 For further information on climate trends, see United States Global Change Research Program, Fifth National Climate Assessment, Climate Trends, https://nca2023.globalchange.gov/chapter/2/.

6 Sarofim, M.C., S. Saha, M.D. Hawkins, D.M. Mills, J. Hess, R. Horton, P. Kinney, J. Schwartz, and A. St. Juliana, 2016: Ch. 2. Temperature-related death and illness. In: The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. U.S. Global Change Research Program, Washington, DC, 43–68. https://doi.org/10.7930/j0mg7mdx

7 For further information on the impacts of extreme heat on human health, see United States Global Change Research Program, Fifth National Climate Assessment, Human Health, https://nca2023.globalchange.gov/chapter/15/.

8 US Global Change Research Program heatwave indicator (https://www.globalchange.gov/indicators/heat-waves)

9 2021 Northwest Heat Dome: Causes, Impacts and Future Outlook | USDA Climate Hubs

10 Urban Heat Islands | HEAT.gov - National Integrated Heat Health Information System

11 Learn About Heat Islands | US EPA

12 See Planning for Urban Heat Resilience, American Planning Institution, April 6, 2022, Planning for Urban Heat Resilience.

13 Ibid.

14 Mapping Campaigns (heat.gov)

15 https://www.miamidade.gov/global/economy/environment/extreme-heat-action-plan.page

16 A Chicago city sensor project goes global | MIT Technology Review

17 https://www.treefolio.org

18 "Smart glass" is coming to a building near you

19 https://www.sageglass.com/case-studies/brownsville-south-padre-island-intl-airport

20 Brownsville South Padre Island Intl Airport | Case Studies | SageGlass

21 https://www.houstonsystem.com/solutions-2/parking-guidance-solutions/

22 Miovision unveils the World's Smartest Intersection in Detroit (asmag.com)

23 Transition to Next Generation 911 (NG911) | CISA

24 https://www.cisa.gov/sites/default/files/publications/21_0707_cisa_california_statewide_ng911_gis_usecase_508.pdf

25 https://www.cisa.gov/sites/default/files/publications/22_0110_s_n_ng911wg_manassas_gis_usecase_508C.pdf

26 The albedo adjustment is an intentional effort to increase the amount of sunlight that is reflected back into space.

27 https://www.sciencedirect.com/science/article/abs/pii/S2352507X24002075

28 GAF's First Urban Heat Project Produces Cool Results | Sustainable Brands

29 Building Resilient Infrastructure and Communities | FEMA.gov

30 NIST Smart Cities and Communities Framework Series | NIST

Homeland Security