Heat Mitigation & Adaptation Guidebook

Strategies for Oklahoma City

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CAPA
strategies

This guidebook was prepared for the City of Oklahoma City
by CAPA Strategies, LLC

Guidebook Overview

As climate change transforms cities and regions across the United States, rising temperatures threaten urban infrastructure, human health, and liveability. In Oklahoma City (OKC), heat has been addressed in existing documents such as plan**okc**, adapt**okc**, and the *City of Oklahoma City Hazard Mitigation Plan Update*. In 2023, the City completed several assessments to better understand local heat exposure and risk. These included a Heat Watch mapping campaign, showing heat distribution across the city; an air quality assessment; and a heat experiences survey which captured residents' experiences with heat, their needs, and coping mechanisms. Of particular interest is how the City and OKC community can build resilience to urban heat and the intersecting hazard of air pollution.

The purpose of this heat-specific guidebook is to offer a range of cooling strategies including and in addition to trees. This guidebook is a resource for municipal staff, partners, and community members in OKC who can help initiate and inform conversations about heat mitigation and adaptation in the city.

Responding to heat will require a mix of mitigation (reducing temperatures and limiting heat exposure) and adaptation (coping when heat cannot be mitigated); physical, social, and policy interventions; and action by the City, professional partners, property owners, and community members. While some solutions can be quickly implemented, others will take months or years to put in place. Solutions exist at the household level and community-wide. As local leaders and residents plan for a hotter future, it will be essential to consider a range of heat mitigation and adaptation options, and select a complementary blend of solutions which meet immediate and long term needs. Ideally, heat mitigation solutions can integrate with existing priorities to address other environmental and health hazards (e.g., air pollution and stormwater runoff). This guidebook presents solutions which are supported by existing literature, and which are suitable for the humid subtropical climate of OKC.

Of the multiple solutions to mitigate heat, literature overwhelmingly emphasizes tree planting and preservation because trees offer numerous co-benefits such as air quality improvement, stormwater retention, flood reduction, improved neighborhood aesthetics, and increased property values. The City of OKC previously examined opportunities for tree planting and the myriad benefits provided by urban canopy in the *Oklahoma City Metropolitan Area Tree Canopy Assessment (2019)*. However, trees are not appropriate in all situations, nor are they the only available option for heat mitigation. Following a summary of the benefits and challenges associated with a tree-based approach, content will emphasize lesser-known options which can support, replace, complement, or amplify a tree-based strategy. The guidebook includes ideas for maximizing the effectiveness and sustainability of various heat mitigation and adaptation strategies, including but not limited to tree-based interventions. This is not a prescriptive implementation plan, but rather an offering of potential solutions to help stimulate and structure ongoing conversations about extreme heat

The content is divided into three sections:

Foundations

This section offers an overview of the climate and environmental challenges faced by OKC, and includes a chapter on the benefits and challenges associated with a tree-based approach to heat mitigation.

City Scale Strategies

This section covers high-level heat mitigation and adaptation strategies which are available to municipal managers and planners, non-profit or community based groups, academic institutions, commercial property owners, business owners, developers, utility companies, and other non-residential entities, as well as multi-family property owners or landlords. These are characterized as built environment and infrastructure; funding, policy and legislation; and social support strategies. The strategies in this section are relatively more expensive and time consuming than those offered as 'Household Scale' strategies, make an impact at a larger scale, and pertain to heat mitigation as well as adaptation.

Household Scale Strategies

This section covers household-level strategies for responding to heat and building resilience. These strategies, which are available to all individual residents and homeowners, are relatively inexpensive, can be implemented on a short timeline, and pertain to heat adaptation rather than broad mitigation. Tips and existing resources for OKC residents are linked at the end of this section.

Overview of the strategies included in this guidebook

Type	Heat Mitigation or Adaptation Strategy	Details
Community Scale	Trees	Planting, maintenance, and preservation
	Green roofs	Vegetated systems
	Reflective and/or light colored materials	High albedo (reflective) roofs; Light colored walls, roofs, and pavements
	Open/green space	Native vegetation; Community gardens; Urban agriculture; Preservation
	Blue-green infrastructure	Bioswales; Permeable pavements; Cool pavement
	Pedestrian and active transportation infrastructure	"Complete Streets;" Bike lanes; Pedestrian safety improvements
	Shading	Non-vegetative shade structures
	Energy efficiency updates	Weatherization; Retrofits (applies to all building types)
	Alternative energy systems	Solar; Geothermal; District cooling; Microgrids
	Legislation and policy changes	Funding; Tree maintenance; Public health
	Financial and technical assistance	Subsidies and rebates; Tree planting and maintenance help
	Community education	Value of trees; Heat safety and risk

Type	Heat Mitigation or Adaptation Strategy	Details
Community Scale	Job training and volunteer corps	Activating community stewards; Building wealth in underserved communities
	Emergency response and resource giveaways	Heat emergency response plan; Cooling resources
	Indoor recreational opportunities	Low cost programs; Subsidies to existing facilities
Household Scale	Small-scale applications of City Scale strategies	Residential tree planting; Green/vegetated, light colored, and/or reflective residential roofs and building materials; Home weatherization; Energy efficiency upgrades and alternative home energy sources
	Maximizing air flow	Strategic use of fans and windows
	Air conditioning and dehumidification	
	Insulation and venting	
	Shades, overhangs and window films	
	Self cooling and rest	Individual, health-based strategies

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Using this Guidebook

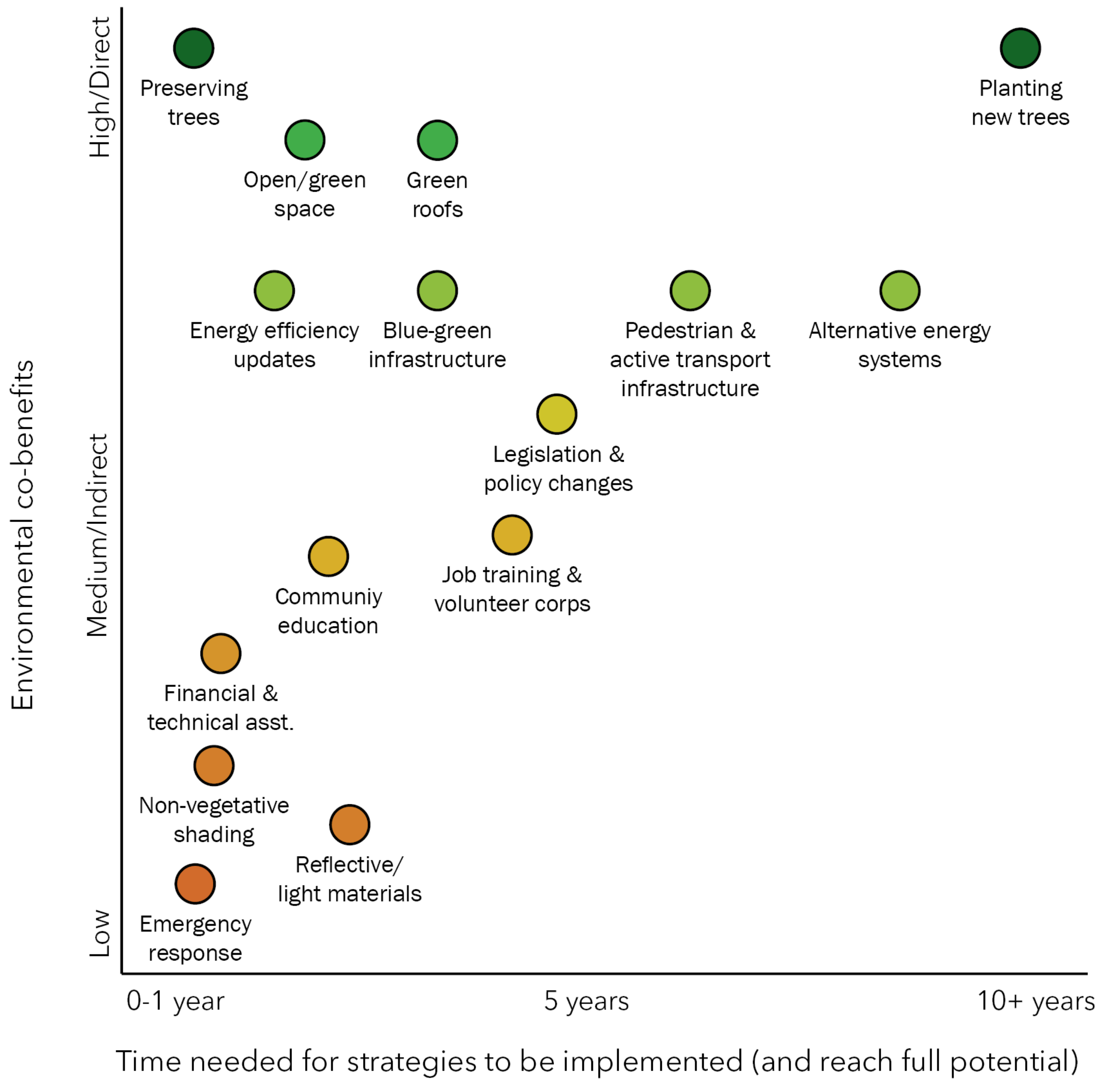
This guidebook is a resource for municipal staff, partners, and community members in OKC who can help initiate and inform early conversations about heat mitigation and adaptation in the city. **Mitigation** measures are about reducing the presence and intensity of urban heat; for example, cutting greenhouse gas emissions, or vegetating concrete surfaces to reduce heat absorption and the intensity of the urban heat island effect. **Adaptation** measures are about adjusting behaviors to cope with heat; for example, opening cooling centers so that unhoused residents or others without air conditioning have a safe place to cool off in the summer, or setting up shade structures to shield people from direct sunlight.

There are various options for addressing urban heat, and many nuances, best practices, costs, and benefits associated with each. The ideas presented here reflect a suite of concepts and interventions that are most appropriate for OKC based on its specific climate and culture. Many of these concepts (e.g., green roofs, weatherization) are tried and true and have been positively assessed in both academic and practical literature; newer concepts (e.g., energy microgrids, "Complete Streets") show promise in the field of heat resilience and are growing in popularity. This guide offers an overview of select mitigation and adaptation options, as well as tips for increasing their efficacy, sustainability, and appeal to local communities. Municipal leaders, managers, planners and their professional partners are encouraged to use this information as a starting point, follow links and references, and dive deeper into the concepts that spark interest. This is not a prescriptive implementation plan, but rather an offering of potential solutions to help stimulate and structure ongoing conversations about extreme heat.

Chapters 1-2 cover foundational information on the climate of OKC, relevant plans and other resources, and details of a tree-based cooling strategy. This content may be of interest to municipal planners and their partners, as well as city residents.

Chapters 3-5 cover heat mitigation and adaptation approaches which could be initiated, funded and managed at the citywide scale. These 'City Scale' strategies are primarily intended for managers and planners, non-profit or community based groups, academic institutions, commercial property owners, business owners, developers, utility companies, district managers, and other non-residential entities, as well as multi-family property owners or landlords.These chapters favor heat mitigation content, though also include opportunities for adaptation. The strategies in this section require more time and money than those offered as 'Household Scale' strategies, but make an impact at a larger scale.

The chart below offers a characterization of the City Scale strategies covered in this guidebook, including timeline (horizontal axis) and environmental co-benefits (vertical axis). **Timeline** refers to the approximate amount of time required to implement a heat mitigation or adaptation intervention, and when applicable, the time required for that intervention to reach its full potential. **Environmental co-benefits** refer to natural hazards and needs other than heat which could be addressed by these solutions. Co-benefits considered here include those related to stormwater and flood management, air quality, carbon capture, and wildlife habitat, all of which could emerge directly as a result of specific heat-related interventions. Some measures do not have direct environmental benefits, but could contribute to them indirectly; for example, job training could lead to improved maintenance of trees, and trees produce co-benefits related to air quality, habitat, and stormwater management. Those measures are identified as having medium/indirect co-benefits in the chart. All representations are generalized estimates and relative to the other solutions presented here. The extent and details of any intervention in practice may increase or decrease its timeline and benefits. This graphic should be used only as a conceptual aid.



Chapter 6 is intended for use by city residents as it covers 'Household Scale' strategies, though the content may also be used by entities working at the City Scale to frame outreach and education. This section covers individual, household-level strategies for responding to heat and building resilience. These strategies are relatively inexpensive, can be implemented on a short timeline, and favor heat adaptation rather than broad mitigation. The final section (6.6) directs readers to existing, user-friendly resources with tips for heat preparedness, safety, and coping mechanisms.

1: Background

1.1 Climate and environmental conditions in OKC

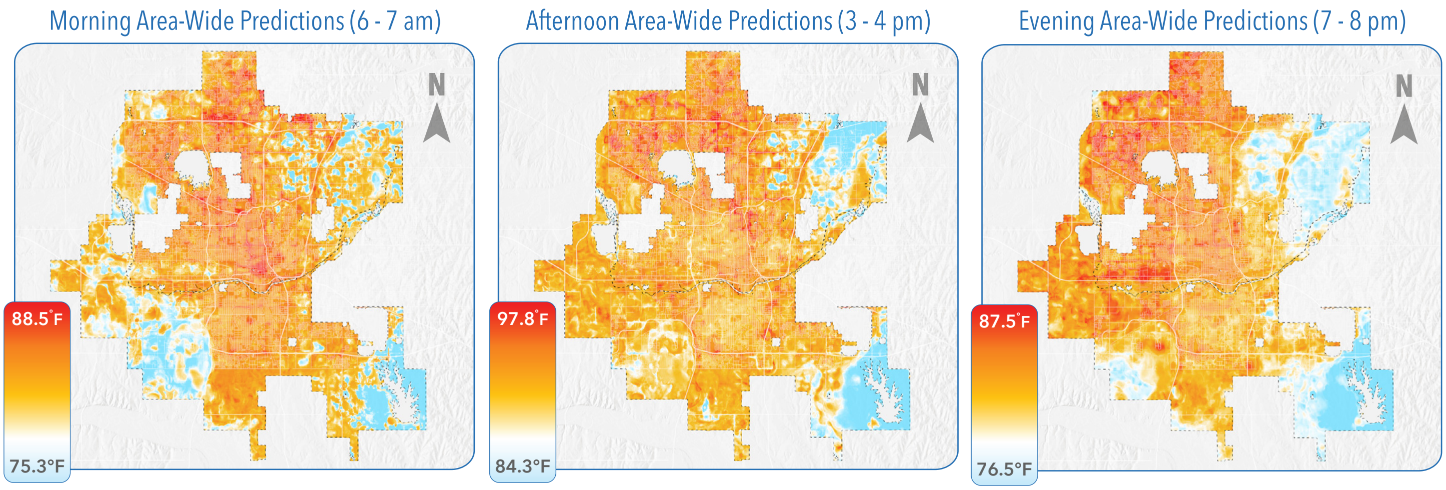
Oklahoma City, OK is located within the humid subtropical climate zone that spans most of the eastern United States. This zone, also known as 'Cfa' in the Koeppen-Geiger classification system (Koeppen-Geiger, 2024), is characterized by warm, wet summers and mild winters. Precipitation occurs throughout the year, peaking in the summer months with the influence of maritime airflow. It is typical for summer temperatures in the Cfa zone to exceed 80° Fahrenheit (°F), and maximum daily temperatures periodically reach triple digits (100°F+). Summer nights are also warm, as humid conditions prevent a rapid cooldown after sunset (Britannica, 2024).

Weather patterns in OKC are consistent with a typical humid subtropical climate zone (Climate-Data, 2024). However, as in many cities worldwide, annual weather in OKC has been undergoing a shift. In 2023, maximum daily temperatures exceeded the 30-year average maximum value 10 times in June, 15 times in July, 18 times in August, and 20 times in September. During these four months, high temperatures at or above 90°F and 100°F were recorded on 73 and 12 days, respectively. The maximum temperature of 106°F was recorded in August, and 10 of 12 100°F+ days occurred in the same month (Weather Underground, 2024[1]). A recent report from the South Central Climate Adaptation Science Center (2020) suggests that temperatures in OKC will continue to rise, with 13 to 28 more "very hot days" (over 100°F) by mid-century. Like all cities, OKC is prone to the 'urban heat island effect.' This means that impervious surfaces absorb heat from the sun while concentrated human activities, such as driving, add heat to the air, leading to higher temperatures in heavily developed areas. More information about climate projections for OKC and about OKC's urban heat can be found on the City's website at: http://okc.gov/climate and okc.gov/ExtremeHeat.

With effects exacerbated by characteristically high humidity in the region, consistent summer temperatures in the upper 80s to 90s pose a significant risk to human health and quality of life. Extreme heat has been tied to increased levels of anxiety, depression, and aggressive behavior (Burke et al., 2018; Miles-Novelo & Anderson, 2019), and can be particularly devastating to the physical health of infants and young children, adults over 65 years old, those who work or live outdoors, and those who are socially isolated (Gronlund, 2014). The situation becomes especially problematic when outdoor air temperature remains high overnight – intensified by a combination of humidity and the urban heat island effect (Taha, 1997) – and human bodies are unable to cool themselves. Sustained, elevated internal body temperature can trigger major health events like heart attack or stroke for those with preexisting health conditions such as cardiovascular disease and diabetes (CDC, 2024a; Gronlund, 2014). Even those in relatively good health can succumb to heat stress or heat stroke, the latter of which can be fatal if left untreated. This is a problem especially affecting athletes and laborers who exert themselves in outdoor heat (CDC, 2024b; Coris et al., 2004). Individuals unaware of the severity of heat risk or the signs of heat-related illness may fail to rest, cool themselves, or seek medical attention at critical moments.

[1] Weather Underground data are derived from a proprietary system called BestForecast™, which relies on over 250,000 weather stations.

Studies by the City and CAPA Strategies have shown that in OKC, as in many US cities, heat is not evenly distributed. Lower-income areas of the city are more built out and less vegetated, and thus experience disproportionately high temperatures. This means that residents with the fewest economic resources to cope with heat – for example, the ability to purchase or run an air conditioner – face the greatest exposure and risk. While heat alone poses a range of concerning threats, higher temperatures are also associated with an increase in air pollution, which similarly affects the city's most economically and medically vulnerable residents, including children, the elderly, and those with pre-existing health conditions (Makri & Stilianakis, 2008). Compared to other natural hazards like flooding, heat generates little physical-infrastructural damage except in the most extreme cases. However, heat waves kill more people each year than all other natural disasters combined, and sustained temperature increases – not just short-lived heat waves – can have widespread public health consequences (National Weather Service, 2024).



Morning, afternoon, and evening area-wide models for distribution of near surface temperature (°F). Source: CAPA 2023 Heat Watch

1.2 Integrative heat mitigation and adaptation solutions

The City of OKC recognizes the need for heat-related interventions, though cooling solutions need not be separated from ongoing environmental management efforts. There are numerous opportunities for heat mitigating infrastructure to mitigate harmful emissions and air pollution (see chapter *3.2 Transportation infrastructure*); to control stormwater flow and flooding (see chapter *3.4 Green and blue infrastructure*); and to alleviate the cost burden associated with commercial and residential energy use (see chapter *3.5 Energy*).

Integrative solutions are highly recommended as a way to maximize the impact of each intervention, minimize redundant work and wasted resources, and tackle climate change as the complex challenge that it is (United Nations Environment Programme, 2021). From a municipal standpoint, heat-related interventions that serve a dual function may be easier to fund because they are a better value than standalone, single-stressor interventions; they may be covered under existing policies and programs pertinent to water management, urban forestry, or environmental health, perhaps reducing the need to pass new legislation; and they may more easily attain community buy-in as they appeal to multiple interest groups. For many of the suggestions provided in this guide, integration and multifunctionality are inherent. However, the City and its partners will need to be intentional in framing heat-related interventions such that those multiple benefits are well understood by funders, the public, and local decision makers. Intentional approaches which link climate adaptation and heat-related action with public health have been particularly popular (Berisha et al., 2017, Casati et al., 2013).

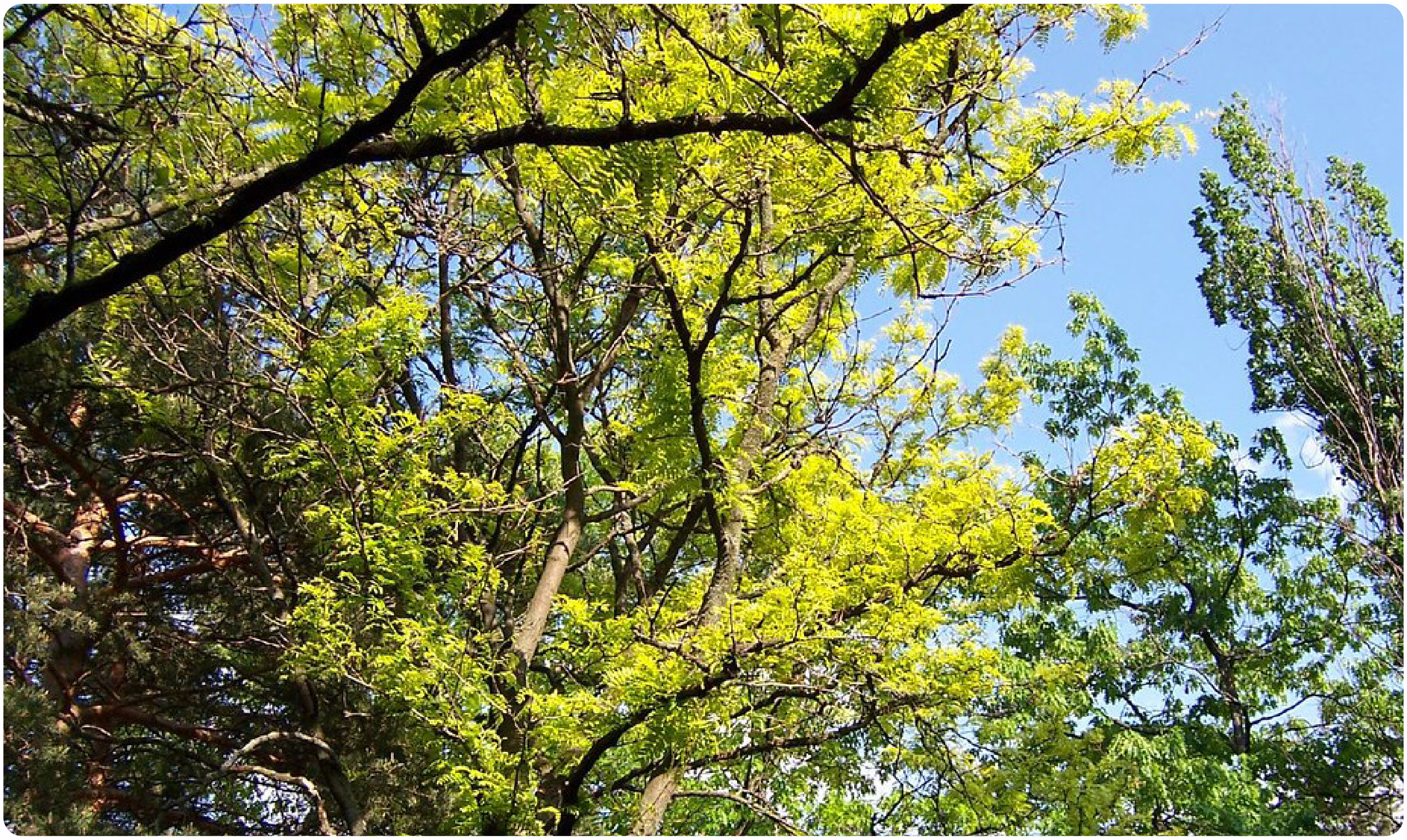
1.3 Existing resources

This guidebook focuses specifically on options for heat mitigation and adaptation in OKC. Such interventions fit into the bigger picture of climate change preparedness, though this guidebook will not delve into climate change adaptation, vulnerability, planning, or mitigation generally. For information on related topics, please refer to the following resources:

- plan**okc**
- adapt**okc**
- City of Oklahoma City Climate Data & Reports webpage
- City of Oklahoma City Extreme Heat webpage
- Oklahoma City Metropolitan Area Tree Canopy Assessment report[2]
- Heat Vulnerability Study (2015-2020) interactive maps
- Oklahoma County Hazard Mitigation Plan
- ACOG Cost of Nonattainment Study for the Oklahoma City Area
- ACOG Comprehensive Economic Development Strategy (CEDS)
- ACOG Climate Priority Climate Action Plan
- Strategies to Address Homelessness in Oklahoma City
- Healthy Trees, Healthy Lives webpage

[2] The current version of the Tree Canopy Assessment report is from 2019, and is due to be updated in the next two to three years.

2: Trees



2.1 Benefits of trees

When cities and communities are planning for heat mitigation and adaptation, trees are often considered the first and best line of defense. This is because trees are uniquely effective at cooling urban environments, mitigating the urban heat island effect, and providing a suite of complementary social and ecological advantages. Trees are an example of a nature-based solution, an approach to climate adaptation which integrates natural features into the built environment. Nature-based solutions are considered more sustainable and cost effective than traditional infrastructure solutions, and simultaneously benefit humans and broader urban ecosystems by working with, rather than against, nature (Cohen-Shacham et al., 2016).

Trees cool the air through the process of evapotranspiration, whereby vegetation releases moisture into the atmosphere (Qiu et al., 2013). This effect is most profound among large stands of trees, such as in dense forests surrounding the city or within well-vegetated parks. Even in smaller quantities, trees provide shade which gives refuge to pedestrians and other commuters as well as those working or recreating outdoors, and keeps outdoor surfaces from absorbing solar radiation. Trees also shade buildings, which reduces the need for energy use to cool indoor spaces. Heat mapping conducted in OKC in 2023 showed that some parts of the city – those least vegetated and suffering the most severe impacts of the urban heat island effect – were up to 14.7°F hotter than the coolest parts. Mapping in comparable climates (Jackson, MS; New Orleans, LA; Richmond, IN) has revealed double-digit temperature variations within cities (CAPA Strategies, 2024). Trees greatly affect temperature in humid subtropical climates and can mean the difference between a comfortable and inhospitable urban environment.

Besides contributing directly to urban heat island mitigation and climate adaptation, trees make urban environments more liveable and aesthetically pleasing, improve health outcomes, increase property values, and reduce crime. They provide wildlife habitat and contribute to biodiversity, clean pollutants such as particulate matter and ozone from the air, filter water, and prevent erosion and flooding (National Wildlife Federation, 2024). Guidance on appropriate trees and plants for Oklahoma City can be found in the tree selection guides *Putting Down Roots* and *Trees and Plants for Oklahoma City*.

2.2 Limitations of a tree-based strategy

Despite their many benefits, trees are not appropriate or desired in every situation. Additionally, trees alone may be unable to satisfy all of a community's interests related to cooling. This means that planners will need to consider alternative solutions for heat mitigation and apply them as needed. Generally speaking, some of the major limitations tree-based strategies can face include:

- City residents may be reluctant to plant trees for a variety of reasons. Common concerns include the upfront costs associated with tree planting and maintenance, and debris or property damage related to trees. Homeowners may not appreciate a tree's broader value to themselves (e.g., future energy savings and increased property values) and their community. While concerns could be overcome through outreach and education in some cases, not all property owners will welcome trees (Riedman et al., 2022).
- Trees require consistent maintenance for their first few years as they put down roots and get established. After establishment, periodic watering and pruning are required. While municipal, private, or non-profit funds may allow for widespread planting efforts, project plans and budgets often fail to account for the ongoing maintenance needs of trees. With no designated party responsible for upkeep, or no funds available to support them, new trees can die before reaching their full potential, or within just a few years of being planted (Pincetl et al., 2013; Widney et al., 2016). In OKC, a 7b hardiness zone, new trees will take approximately six months to grow each inch of trunk diameter (University of Florida, 2020).
- Urban areas which have been heavily developed may lack space for new trees. Making space requires major changes to the built environment such as de-pavement, or the taking of land already in use for another purpose. These kinds of changes can be costly, politically difficult, and logistically challenging to implement.
- Trees compete for land area with equally valuable uses like homes and businesses. Efforts to expand affordable housing, keep urban sprawl out of undeveloped areas, and make neighborhoods and cities more walkable all depend on placing homes and businesses in closer proximity to each other (i.e., increasing density). However, this leaves less open space for trees in developed urban areas and requires consideration of tradeoffs and benefits.
- The presence of power lines and utility lines – including those underground such as water, sewer, stormwater, oil and gas – creates a conflict for space, may lead to over-pruning of existing trees, and limits the potential placement options for new trees. According to the Oklahoma Administrative Code Title 165, utility companies are required to develop an annual vegetation management plan with details on tree pruning, removal, and control to limit such conflicts (State of Oklahoma, 2020).

- Trees cool the atmosphere via evapotranspiration but do not alleviate humidity. In OKC, the combination of high temperatures and humidity may mean that humans have a harder time with natural thermoregulation via sweating (Raymond et al., 2020). If heat and humidity become high enough, even in the presence of trees, residents will need cool and dehumidified spaces to seek refuge, such as an air conditioned indoor space.
- Trees have been shown to increase property values, which is usually thought of as a benefit. However, studies have also shown that the uneven installation of green infrastructure (including trees) within cities can sometimes lead to a process called 'green gentrification' years later (Anguelovski et al., 2022; Gould & Lewis, 2016). In these cases, green amenities in previously underserved areas can trigger an increase in property values, taxes and rents, attract new businesses and residents, and lead to the displacement of longtime residents. If not addressed intentionally by city planners and policy-makers, this outcome could harm those communities who were meant to be served by greening.

2.3 Making the most of trees

When trees are utilized for heat mitigation (and other environmental purposes) there are several steps that can be taken to increase the chances of success and sustainability.

- Multiple studies of humid subtropical climates have shown that the cooling benefits of trees level off when coverage reaches around 30% (Ng et al., 2013; Onishi et al., 2010; Ouyang et al., 2020);

one study put this number as high as 40% (Ouyang et al., 2020). The 40% value is thought to be most effective at a small scale (i.e., block level) while the 30% figure may be a sufficient citywide target. Although cooling benefits level off, greater tree coverage could better address non-heat stressors such as flooding and air pollution. The *Oklahoma City Metropolitan Area Tree Canopy Assessment* found that communities in OKC currently have 27% tree cover on average, and together could support over 50% cover.

- Native species are preferable because they are climate adapted, complement other natural components of the urban ecosystem, and have deep roots which capture stormwater and help trees withstand flooding. Deciduous trees provide the most effective shading and cooling in the summer, while allowing sunlight exposure in colder months when leaves fall (Antoszewski, 2020; National Wildlife Federation, 2024). This means that deciduous tree-shaded buildings can enjoy low cooling burdens in the summer without added heating burdens in the winter. Due to climate change and pests such as emerald ash borer, some native tree species may become less suitable over time. It is recommended that the City of OKC devise a list of native and non-native species which can survive in projected future conditions and plant them as conditions become appropriate. The City's current tree selection guide, *Trees and Plants for Oklahoma City* (2016), is available here.
- The right configuration of trees will depend on communities' goals and the urban context. A combination of configurations across the city may be most appropriate and feasible. A cluster of trees in a single location (e.g., a forest) offers greater benefits in terms of air purification, stormwater control, and localized heat mitigation; while the same number of trees spread equally over a large area (e.g. an entire city) will have less pronounced long-term ecological effects, but will positively impact a greater number of urban residents in the short term (Heynan, 2003). Placing trees within green space or near water features will maximize their cooling potential, and trees will have the greatest cooling effect in front of facades with a south-west exposure (Antoszewski, 2020; Yu et al., 2017). Options for tree placement and configuration may be explored using the online platform i-Tree.
- Engaging with local communities, obtaining public buy-in, and considering anti-displacement measures from the start will ensure that tree planting projects respond to community interest and needs, that trees will be welcomed and cared for, and that greening does not cause unintended harm to vulnerable residents (deGuzman et al., 2018). Direct engagement with residents and property owners may allow the City to leverage a cache of privately-owned planting space – including residential yards, parking lots, and commercial landscapes – which could be planted and maintained by those property owners.
- Street trees can be particularly valuable as they shade large areas of asphalt near homes, improve the pedestrian environment, thereby encouraging walking, and help to reduce vehicle speeds, enhancing neighborhood safety.
- With any major tree planting initiative, the City and partners should create a plan for at least three to five years of monitoring and maintenance, including a regular watering schedule. This plan should clearly designate the responsible entities and funding source to cover maintenance staff salaries, tools and equipment, water, and logistical planning (e.g., establishing an annual rotation for pruning). Assessments from Portland, OR (Davey Resource Group, 2009) and Los Angeles, CA (Hellman et al., 2024) indicate that a robust tree maintenance program could cost ten of millions of dollars, though the exact price will vary depending on city size, cost of labor, number of trees, and other factors. Options for funding can be found in chapter 4.1.

- Tree-based heat mitigation strategies should prioritize the preservation of mature canopy as well as new planting. Fully grown trees are up to 70 times more effective than saplings at capturing carbon, mitigating heat, and controlling stormwater (Stecker, 2014; Treekeepers of Washington County, 2024).

2.4 Community and political interest

In 2023, the City of OKC conducted a "Summer Heat Experiences" survey with local residents. In addition to questions about residents' exposure to heat and air pollution, their coping strategies, and their existing knowledge about urban heat, the survey asked participants about their interest in trees and green space. While over 90% of respondents agreed with the statement "We need more trees and green space in OKC," only around two-thirds (64%) agreed with the statement "We need more trees and green space in my neighborhood." This result held for ZIP codes which were determined by the City of OKC to have a high heat vulnerability index and which are known to feature relatively low canopy and high temperatures. Additionally, while over 90% of respondents would support "planting more trees on public property," only 74% would support assistance for homeowners to plant or maintain trees on private property. These results suggest that OKC residents are in favor of trees, but may not wish to be responsible for them or to face potentially damaging consequences as noted above. There is an opportunity to engage with residents and share information on the benefits of trees to assuage concerns. For example, less than one third (30%) of respondents indicated that they were well informed about how trees keep the urban environment cool. If future forestry efforts target low-income communities in order to advance equity, the City should engage with residents early on to ensure that planting projects are welcome and do not create unwanted burdens. The "right tree, right place" approach provides flexibility in selecting trees that will have a minimal impact on homeowners and/or have minimal maintenance requirements (Arbor Day Foundation, n.d.).

Policies and goals set out in recent plans and ordinances provide a strong basis from which the City of OKC can champion tree planting and preservation measures in the future. For example, street trees are required in Urban Design districts per the OKC Municipal Code. Other policies of note include G-2, G-21, G-25 and G-29[3] from *plan**okc***, and NB-16[4] from *adapt**okc***. The OKC municipal code – Article XI. Landscaping and Screening Regulations – currently offers some support for trees, stipulating that "any Significant Tree claimed for points that dies during construction, or as a result of construction, shall be replaced with a tree (or trees) to equal or exceed the point of value of the lost tree." Additionally, landscaping requirements state that for single family residential developments, "within the perimeter yards, there shall be at least one medium tree planted and/or maintained for every 75 feet, or fraction thereof, of frontage with a minimum of one tree per lot" (Oklahoma City, 2024). These policies and requirements can be referenced when advancing new projects or legislation in the city.

[3] G-2: Revise development regulations to require the following factors to be addressed in development and redevelopment proposals: • Preservation of existing natural resources
G-21: Develop a manual of best management practices that can be integrated into City codes.These include, but are not limited to: • Tree care and management. • Tree planting. • Tree protection.
G-25: Develop and adopt a tree preservation ordinance
G-29: Pursue methods to reduce the impact of the urban heat island effect on Oklahoma City by: • Establishing a minimum canopy coverage requirement over paved surfaces • Instating a "continuous canopy" requirement

[4] NB-16: Develop and adopt a tree preservation ordinance

3: Built environment and infrastructure

3.1 Building codes

The hard, impervious, built-out quality of urban areas is a key factor in the development of the urban heat island effect, whereby urban structures trap heat and release it slowly throughout the day and night. Large buildings (e.g., commercial or residential high rises, office parks, university facilities, shopping centers) are ubiquitous in urban areas, contribute significantly to the urban heat island effect, and are therefore a logical target for heat mitigating interventions. Often, cities achieve changes to the built environment by imposing new building codes, requiring sustainable practices and certifications, such as LEED or Energy Star. However, because Oklahoma is subject to the Dillon Rule, which prevents deviation from statewide building standards, OKC is limited in its ability to impose new codes. The State of Oklahoma has adopted the 2018 International Building Code (IBC) and 2009 International Energy Conservation Code (IECC), the latter of which sets building envelope standards for new commercial construction. The IECC offers minimum requirements for insulation, but does not mandate specific efficiency certifications such as LEED, cool building materials, or retrofits to existing buildings. If City staff would like to see efficiency and sustainability standards implemented for new developments, options to work around the Dillon Rule include:

- Focus on incentivizing, rather than mandating, green building practices. This can be done, for example, by offering a density bonus for large buildings, or waiving permitting or development fees when developers comply with LEED or similar standards.
- Establish a green building fund to help the owners of existing buildings pay for retrofits and sustainable upgrades. This can be paid into by developers whose new properties do not conform to green building standards.

- Mandate performance outcomes rather than building codes. In other words, the City can mandate that all buildings meet certain efficiency or heat mitigation goals by a future date without mandating that property owners take specific actions to reach those goals. This approach may be established through a resilience zoning ordinance (see case study example below). In order to allow a variety of new and old structures to meet resilience zoning criteria, offer a flexible menu of options that developers and property owners can choose from.

Sustainable building goals include:

Cool roofs and vegetation

Incorporating green spaces means that buildings will be cooler inside and require less energy use, that stormwater will be better captured and retained in highly developed areas prone to runoff, and that habitat is provided for birds and other wildlife.

- New developments incorporate eco roofs (also known as green roofs), and/or provide adjacent, ground-level vegetated space and landscaping maintenance, either on private grounds or in the public right of way.
- New developments requiring the removal of mature trees incorporate a minimum number of replacement trees on the property.
- Reflective and/or light colored roofing materials are an alternative to green roofs, provide similar indoor cooling benefits, require less regular maintenance, and may be suitable for older buildings or those that cannot support the weight of a green roof. However, reflective and light roofs do not contribute to stormwater management. Light colored walls and pavements can also be incorporated to reduce heat absorption.

Energy use and emissions

- Buildings meet appropriate standards for energy efficiency and achieve or demonstrably work toward net zero emissions within a reasonable time frame.
- Incentives and regulations based on efficiency may encourage developers and property owners to pursue clean energy systems, implement passive cooling measures, and utilize heat-mitigating solutions such as green or reflective roofs which improve indoor conditions on hot days. A reduction in energy use contributes to a decrease in carbon emissions and overall warming.

Considerations:

New building standards and incentives as described are more easily applied to new structures, though older buildings are also in need of retrofits and energy efficiency upgrades. Owners of existing buildings may respond to education and outreach, or opt for upgrades with financial support.

It may be difficult to implement green roofs or adjacent vegetation on or around existing buildings if an older structure cannot support the weight of a green roof, or if there is no adjacent space to work with. Such strategies could be applied to new buildings, while older buildings can more readily comply with reflective and/or light colored roofing or energy efficiency standards.

Although reflective roofs are an effective strategy for reducing indoor temperatures, reflective pavements and walls are not recommended in areas with high pedestrian traffic. These can bounce heat back on to pedestrians and increase ambient temperature at the street level (Bloch, 2019).

Standards and incentives which encourage new developments to incorporate trees or green space will not be effective in the long term if no agreement is made regarding maintenance and upkeep. If a developer cuts down mature trees and replaces them with saplings which are allowed to die within a few years, the positive effects on heat mitigation will be negligible (Widney et al., 2016).

Case Study:

OVERCOMING THE DILLON RULE IN ARLINGTON COUNTY & NORFOLK, VIRGINIA

Arlington County has successfully navigated the Dillon Rule limitation by incentivizing, rather than mandating, green buildings for over two decades. The County encourages compliance with green building best practices by offering a density bonus – which allows developers to get more out of a limited space – to new developments achieving LEED and/or Energy Star certification. The County has also established a Green Building Fund. New developments that do not comply with LEED standards are assessed a fee, and the resulting fund is used to provide education and support to developers engaged in green building practices (Arlington County, 2020). Norfolk has recently adopted a resilience zoning ordinance which requires developers to achieve a "resilience quotient" by gaining "points" through sustainable building practices. Developers who do not meet new standards are subject to a more intensive site review process (Pew, 2019). Although Norfolk's approach emphasizes coastal flooding resilience, the same strategy could be applied with an emphasis on heat.

3.2 Transportation infrastructure

Like buildings, automobiles are ubiquitous in urban areas and exacerbate the urban heat island effect locally, while contributing to emissions, warming, and air pollution at a larger scale. Prioritizing public and alternative transportation in OKC is a way to simultaneously mitigate heat, reduce emissions and air pollutants, and promote community health via active transportation (Glazener & Khreis, 2019). A 2015 review by the University of Oklahoma Institute for Quality Communities found that OKC had some of the lowest rates of commuting by active transportation (i.e., walking, biking, or taking public transportation) among large cities in the country. Encouraging more active transportation in the future – which can improve human health and mitigate urban heat as well as harmful air quality – requires a careful elevation of alternative options. Specific strategies include adding new bike lanes to larger thoroughfares, and/or designating select small roads as bike-only thoroughfares closed to non-resident traffic; creating safe walking paths; and increasing the reach of bus routes and frequency of trips.

A 2016 study by the Lynn Institute for Healthcare Research found that in Northeast OKC, residents struggled with insufficient and under-maintained pedestrian infrastructure and lacked a personal vehicle. Pedestrian infrastructure improvements may encourage new active commuters while creating safe spaces for those without an alternative means of transportation. Options include adding more sidewalks, repairing broken or uneven sidewalks, adding street lighting, and placing safety barriers between pedestrians/bike lanes and automobiles.

"Complete Streets" design policies guide the integration of pedestrian- and alternative transportation-friendly infrastructure into urban development (Jordan & Ivey, 2021). The Association for Central Oklahoma Governments (ACOG) has recently adopted a "Complete Streets" resolution, and the City of OKC a related "Liveable Streets" resolution.

Greater opportunities for public and active transportation mean more time spent outdoors in the heat and, in the case of active transportation, increased physical exertion. This also means that upgrades to pedestrian and commuter heat safety infrastructure will be needed (Karner et al., 2019). Examples include providing shade at bus stops, and placing public water fountains or misting stations along popular commuter routes (Lanza & Durand, 2021). Additional tips include placing new bike or walking paths close to existing tall buildings or trees, which provide shade; and utilizing permeable and/or light pavements along pedestrian and bike paths to cool the path surface and assist with stormwater capture (United Nations United Nations Environment Programme, 2021).

Considerations:

Any expected increases in the frequency of active transportation (walking, biking, skating, etc.), should be coupled with appropriate public health messaging and safety warnings during high heat events, particularly when humidity or air pollution are also high.

"Complete Streets" policies often call for trees or other street vegetation to provide shade and reduce the urban heat island effect. If funding and capacity for street tree maintenance are limited, or if there are unclear roles related to public tree care, such changes may be difficult to implement or maintain. As noted in chapter 2, new planting projects should plan for multiple years of tree care.

Some of the highest need areas may be the least vocal or visible, and could be left out of City-sponsored transportation improvements. The City should look at different indicators of need and risk, and collaborate with community members in identified areas to design projects that work for them.

Case Study:

PITTSBURGH, PA COMPLETE STREETS INITIATIVE

The City of Pittsburgh once used 311 (City Response Center phone line) data to determine where to make street safety improvements. However, through an examination of crash data, it was later discovered that this approach missed key areas of the city because low-income communities of color were not making regular use of the 311 system. Through the "Complete Streets" program, the City of Pittsburgh redirected funds and attention to a high-need, high-crash area that had previously gone underserved. The City worked with community members to design a project that responded to their challenges. The resulting project prioritized safe routes to school for children, and improved road conditions for both drivers and pedestrians (Smart Growth America, 2019).

3.3 Non-vegetative shading

Offering people, pets, surfaces, and structures the opportunity to avoid direct sun exposure is an effective way to reduce heat stress and the urban heat island effect. Large trees create shade while offering environmental co-benefits, though as noted in chapter 2, capacity and funding limitations could create maintenance challenges for City of OKC staff. Trees may also not be a good fit in all high-traffic areas, such as sidewalks or other paved spaces, and areas without proper soil, drainage, or irrigation. Non-vegetated shade structures serve a similar heat mitigation function but require less upkeep compared to trees and have a more immediate cooling impact.

Tips for effective shading (United Nations United Nations Environment Programme, 2021):

- Prioritize busy commuter routes for shading upgrades (Jay et al., 2021). Areas where people congregate, such as playgrounds and picnic areas, can also be prioritized for shading.
- Aim for at least 30% shade coverage along transit paths, and consider how shade structures will behave at different times of day and with different sun angles.
- Shade areas where individuals will be resting or waiting (benches, bus stops). Pergolas and shade canopies are popular options for this purpose.
- Note that paths or sites with east-west exposure will require more shading than those with north-south exposure.

Permanent shade structures can provide co-benefits when outfitted with a green roof or solar panels. Large installations in parking lots, at transit centers, or on school campuses may be particularly effective at reducing outdoor heat exposure in locations where people are commonly susceptible.

One study of artificial (i.e., non-tree) shade structures in a humid subtropical climate found that areas shaded by pergola with some overhead vegetation, or shaded by a building, could feel nearly 30°F cooler than those receiving direct sunlight, (Watanabe et al., 2014). Another found that shading, whether by natural or artificial means, reduced thermal stress by more than half and that the effects of artificial shading closely resembled those of tree shade (Ouyang et al., 2023). Tree shade is known to reduce surface temperature and improve pedestrian thermal comfort in humid subtropical cities; benefits that can be effectively mimicked by non-vegetative shade structures.

3.4 Green and blue infrastructure

When we think of 'green infrastructure' (GI), trees and other forms of vegetation may come to mind. However, GI and blue-green infrastructure (BGI) also includes green walls and roofs, permeable pavements, and bioswales. GI is prized as a nature-based solution which provides cooling benefits, water management and flood control, pollution mitigation, wildlife habitat, and aesthetic improvements. In highly built-out areas it may be challenging to secure space for trees or other forms of (B)GI. Taking space which is already dedicated to another purpose (e.g., parking) can become contentious. As the City negotiates larger transformations (if desired), small advances can be made by placing (B)GI assets among existing built spaces without interrupting their function; for example, lining a parking lot with trees or cutting a bioswale into a sidewalk during the course of regular maintenance. These alterations can still have a measurable impact on surrounding heat conditions and require relatively little transformation to the built environment.

The use of (B)GI is recommended as a heat mitigation and adaptation strategy, though there are specific details to be aware of when choosing the right approach for OKC's humid subtropical climate.

<u>Trees</u>

- Street trees distributed throughout densely populated urban areas have a greater effect on thermal comfort than do trees clustered away from human activity zones (Kong et al., 2017; Wang et al., 2021a).

- In a humid subtropical climate, canopy coverage of 30-40% should produce the maximum potential cooling benefit. While OKC's communities already have an average canopy coverage of 27%, that value is not evenly distributed in all neighborhoods across the city. It is recommended that at least a 30% target be applied at the citywide scale and 40% at smaller scales such as individual blocks, with attention to controlling any loss of existing canopy (Ouyang et al., 2020).
- Leafy, broad canopy trees will be the most effective for shading and heat mitigation, though other species could contribute more to stormwater management or air pollution reduction.

<u>Green roofs</u>

- When buildings can support them, green roofs are ideal for humid subtropical climates which receive ample precipitation and have a need for stormwater capture.
- The presence of green roofs has a minimal impact on ambient outdoor temperatures at the pedestrian level, though can reduce localized air temperature by up to 5°F (EPA, 2024a). Green roofs and walls can effectively reduce indoor temperatures, and offer insulation which reduces energy burdens for cooling. Green roofs are especially effective in single story structures and reduce stormwater runoff in addition to cooling the air and building surfaces (Daemi et al., 2021; Saber, 2022).
- The presence of a green roof may increase the cooling capacity of other passive measures such as nighttime building ventilation (Ran & Tang, 2018).

- Plants that are native to the region, hardy, low-lying, and that can survive on rainwater precipitation may be preferable as they require minimal maintenance. Species that can handle extensive direct sunlight, hold water, and reseed themselves, such as succulents, should do well on green roofs (Getter, 2015). If a building can support the weight of heavier vegetation, and if staff capacity allows for regular maintenance, taller, less hardy, or more labor-intensive shrubs, grasses, and other plants could be selected (National Park Service, 2022). Selections depend on what plants can survive in rooftop soil depths, aesthetic preferences, a desire to support certain insect or bird species, and other factors.

Open/green space

- Vegetated open spaces, typically found in the form of urban parks or plots of grass, are less effective than trees but more effective than green roofs at reducing the urban heat island effect and outdoor surface temperatures.
- Open, green spaces are most effective for cooling when they appear in compact and simple shapes such as a circle or square (Li et al., 2012; Shih, 2017).
- The permeability of open, green spaces means that, at minimum, they can provide a stormwater control function. The cooling function of grassy open spaces is improved when trees are distributed throughout (Yu et al., 2017), such as in parks. When possible, native grasses should be prioritized over turfgrass as they provide added benefits for stormwater management, soil quality, and wildlife habitat.
- Community gardens and urban agriculture sites can also serve as cooling green spaces and, depending on the density and type of vegetation, may serve a greater cooling function than turfgrass-only spaces. These sites offer the added benefit of food production and community building for those who live in the area. Rainwater harvesting on-site offers a sustainable option for watering trees, crops, and other vegetation.

Blue-green infrastructure

- Blue or paired blue-green infrastructure (BGI) is commonly thought of first as a stormwater management solution, and is therefore favored in humid subtropical climates which experience year round precipitation and flooding.
- Forms of BGI such as bioswales, vegetated retention ponds, and permeable pavements reduce the prevalence of impervious surfaces and potentially increase the presence of vegetation in the city, thus contributing to an overall reduction in the urban heat island effect and outdoor temperatures while controlling stormwater (Liao et al., 2017).
- Trees, native vegetation, and green spaces have been found most effective for cooling when located near a body of water, whether natural or manmade. It is recommended that GI and vegetation be placed near water features when possible (Yu et al., 2017).
- Other blue infrastructure solutions which serve the purpose of heat adaptation rather than mitigation include drinking fountains and/or water bottle refill stations in high-traffic public places, and misting stations or splash pads in city parks.

Considerations:

As with trees, all forms of green and blue-green infrastructure require regular and ongoing maintenance (Lamond & Everett, 2019). Plans for maintenance, including funding, should be put in place prior to the implementation of any new (B)GI projects. This may require coordination between departments such as Public Works and Parks & Recreation. Although (B)GI can mitigate urban heat, proposed projects might highlight its flood mitigation benefits. Flooding is a more expensive and physically damaging environmental stressor and may receive greater interest from decision makers or funders. Native plants used in (B)GI are expected to require less maintenance and fewer resources than non-native plants.

Also like trees, different forms of (B)GI have the potential to trigger an increase in property values, green gentrification, or daily inconveniences for the populations they are meant to benefit. It is recommended that City staff consult with local community members to ensure that projects are welcome and will not create an unintended burden.

3.5 Energy

Shifting to clean, renewable, alternative sources of energy is associated with a decrease in greenhouse gas emissions which contribute to climate change. Such shifts at a large scale are necessary if cities are to meet ambitious emissions targets and attempt to mitigate rising temperatures. Energy efficiency also amounts to cost savings on household and business utility bills (US Department of Energy, 2015). While this is an excellent perk for city managers and businesses, it can be lifesaving for residents who cannot afford to run an air conditioner but are unable to cool their homes through other means. Additionally, greater energy efficiency and the availability of multiple energy sources means that power grids are less susceptible to failure during extreme heat events when demand is high, a problem that has occurred across the US with growing frequency (Stone et al., 2021). For municipal and large private or commercial structures, the following options may be considered:

- Weatherize, electrify, and update insulation in existing structures, and ensure that new buildings meet efficiency standards and incorporate passive cooling measures (through building code incentives and recommended standards that OKC may identify, per section 3.1). These changes can be sought through incentive programs rather than government mandates. Coupling efficiency upgrades with pre-planned building renovations can be an effective access point for older buildings. Passive cooling principles to consider include building orientation and building materials that reduce heat exposure and retention; proper insulation and shading; and the use of natural ventilation when possible (United Nations Environment Programme, 2021).
- Install geothermal energy pumps, or install solar panels atop structures that can support them. The typical weather patterns of OKC are compatible with solar energy generation and use.
- Implement a district cooling (or joint heating-cooling) model (Inayat & Raza, 2019). This system involves the delivery of chilled water to multiple buildings from one centralized location. It is more efficient and environmentally friendly than cooling individual rooms or structures through separate air conditioning systems, and is appropriate for clusters of large buildings, as one would find in a city center. Notably, district cooling is easier to implement in new development areas where several structures are being built around the same time.

At work, home, school, or in cooling centers, access to air conditioning in a heat emergency is an essential adaptation, especially for heat-sensitive populations. Some residents cannot afford the energy burden of running an air conditioner, and therefore lack access to this basic cooling resource even as people are increasingly turning to air conditioners for relief. At the same time, ever growing demand strains local energy resources and can lead to blackouts with potentially devastating consequences in a heat wave (e.g., loss of cooling, loss of access to functioning medical equipment or refrigerated medication). When it comes to protecting the energy grid and ensuring that residents can cool their homes, behind-the-meter (BTM) energy systems and/or microgrids may provide an answer (Marsh, 2023).

- BTM energy systems can be implemented widely through building-specific solar projects. The City of OKC and non-profit partners may work with homeowners across the region to increase the uptake of solar panels, resulting in energy storage and a safe, legal residential backup in the event of failure in the main power grid.
- Microgrids are shared energy systems that potentially support the use of alternative energy (solar, geothermal), promote energy independence for underserved communities, and offer a safety net in a heat emergency (Gastelum, 2022). Typically, sustainable energy sources charge batteries for use in a blackout and may also power homes or businesses within the microgrid on a regular basis. Microgrids may take a variety of forms depending on local conditions, needs, and access to technical and financial resources. Recent case study examples that may provide some inspiration include Brooklyn, NY and Humboldt, CA (Goodwin, 2019) as well as Boston, MA (see below). Types of microgrids that could be most appropriate for OKC include (Think Microgrid, 2024):
    - Campus: serves buildings on a single, large piece of land such as college or medical campuses
    - Community: serves critical facilities, homes, businesses, and/or other community buildings
- While the types listed above can be set up BTM, a third type of microgrid, “grid-connected,” does interact with a city’s main power grid and utility. A grid-connected system is not recommended for OKC given anticipated pushback from investor-owned utilities.

Consideration:

The implementation of microgrids or individual BTM energy systems, including subsidies for low-income residents to access alternative energy infrastructure (e.g., solar panels), would require significant upfront investment by the City or other funding partner.

Case Study:

BOSTON, MASSACHUSETTS MICROGRIDS & RETROFIT PROGRAM

The Greater Boston metropolitan region contains multiple environmental justice communities which have been disproportionately exposed to environmental hazards, social marginalization, and economic disinvestment throughout the city's history. Two such localities, Chelsea and Chinatown, are expected to bear the brunt of climate change, from sea level rise to extreme heat and weather events, while the entire urban metro suffers from aging infrastructure. In order to build resilience and secure their energy futures, these two communities are working toward the nation's first cloud-based microgrids. With support from local non-profit groups, designated facilities in Chelsea and Chinatown will be retrofitted with solar panels and green generators which can collect and store energy, and run on battery power during an outage or peak use of the citywide grid (Climable, 2024; Gastelum, 2022; Gellerman & Greene, 2021).

Additionally, the City of Boston recently launched the 'Healthy & Green Retrofit Pilot Program,' which incentives owner-occupants of multi-family housing properties to electrify their buildings. Selected participants in the pilot program will receive a retrofit consultation from a decarbonization advisor and $50,000 for upgrades. The program is intended to make multi-family housing more comfortable and more sustainable for all tenants through additions such as air conditioning, solar panels, and improved ventilation and insulation (City of Boston, 2024).

4: Funding, policy and legislation

4.1 Funding

Heat-mitigating infrastructure – especially green infrastructure (GI) – requires ongoing maintenance to function effectively over the long term. Maintenance can take the form of activities like watering and pruning trees, removing debris from bioswales, or cleaning permeable pavements. Failure to plan for maintenance is a common problem which prevents GI from achieving its heat mitigating potential or providing lasting relief. The City would need to identify viable and sustainable sources of funding to cover the cost of initial implementation, as well as long term maintenance to ensure sustainability (Baietti et al., 2012). Some possible routes for securing funding are described below:

- Clear policies can dictate how the City collects fees and from whom, and clarify what kinds of funders the City may partner with.
- User service fees and voter approved taxes (e.g., levies, bonds, etc.) on city residents are a possible strategy for funding GI (and general infrastructure) maintenance as they provide a steady stream of income which can be directed to that purpose. For example, the City of Tulsa collects a Stormwater Utility Fee which helps to fund the maintenance of stormwater infrastructure (City of Tulsa, 2024). New and modified taxes and fees can be levied as major projects emerge, though such fees may receive pushback from residents if the benefits are not clearly conveyed. These may take various forms such as a stormwater treatment fee, income tax, business tax, or sales tax (Zimmerman et al., 2019). On-street parking fees could be directed towards street tree planting and maintenance. Permit or development fees imposed on new developments offer a one-time infusion of funding but are not reliable as a means of supporting ongoing maintenance (Mell, 2018).
- Non-fee based options for funding GI and other heat-mitigation projects (Zimmerman et al., 2019):
    - Federal Grants from entities including the Environmental Protection Agency (EPA), the Federal Emergency Management Agency (FEMA), Housing and Urban Development

(HUD), the Department of Agriculture (USDA) including the US Forest Service, and the Department of Transportation (DOT)

- Grants from State agencies such as the Oklahoma Water Resources Board and the Oklahoma Conservation Commission
- Bonds from governments, corporations, financial institutions, or investors including revenue bonds, industrial revenue bonds, green bonds, qualified energy conservation bonds, climate bonds, social impact bonds, environmental impact bonds, and catastrophe bonds
- Donations from philanthropic organizations, charitable trusts, or private businesses

Case Study:

LANDSCAPE BONDS IN NORMAN, OK

In OKC, despite landscaping ordinances, it is not uncommon for developers to let new trees or plants die without replacing them. In Norman, OK, officials have addressed this issue in part through the use of landscape maintenance and replacement bonds. Under the current system, developers are required to sign a bond pledging to maintain vegetation at new development sites for a period of three years, and must make an upfront payment to be held as collateral (City of Norman, 2020). There is not a strong base of evidence to quantify the effectiveness of landscape and replacement bonds. Anecdotally, this program has been successful in Norman and could serve as a model for neighboring OKC. One potential limitation is the availability of staff in OKC to monitor for violations and enforce landscaping ordinances. Currently, City staff capacity does not allow for extensive monitoring overall. With regard to landscape bonds, a staff liaison might be assigned to monitor landscaping outcomes as new development projects are initiated.

Considerations:

Making the case for funding GI can be a challenge because its economic benefits are not immediately clear. It may help if the City can articulate, in dollars, the expected cost-savings associated with GI effects, such as flood damage mitigation and reduced health care costs (Jaluzot & Ferranti, 2019). Additionally, messaging which highlights the co-benefits of GI and other heat-mitigation infrastructure can improve public or funder receptivity (Droste et al. 2017).

Single-source funding streams are easier to manage but more prone to failure when circumstances change (e.g., when a supportive funder or political ally leaves an organization). Multi-source funding streams are recommended, and may mean that the City partners with County or State entities, charitable groups, investors, and/or private businesses in addition to levying fees and use taxes (Droste et al., 2017).

4.2 Tree and open space preservation

Many cities have articulated policies and goals that would benefit urban trees. For example, comprehensive and climate action plans from cities like Kansas City, MO (2022), Charleston, SC (2021), and Dallas, TX (2020) set goals for tree planting, maintenance, and/or preservation. The local *plan***okc** includes several such goals and policies. Establishing standards through plans is an effective way to articulate the problem and possible solutions, and normalize the idea of greater support for urban trees or other forms of green infrastructure. One challenge is that goals and policies are not always legally binding. OKC might consider opportunities to craft new legislation in order to codify some of those goals. Legislation that establishes protections, makes tree removal more difficult, and/or commits funding and staff time to the care of trees are all options to improve outcomes in the urban forest. Guidance on developing a municipal tree ordinance is available from Arbor Day Foundation here.

Urban trees are a frontline defense against the urban heat island effect and can have a significant, day-to-day impact on those who live or work in the city. Tree preservation and maintenance are essential strategies for cooling busy urban centers. While vegetated open spaces and natural areas do not provide the same amount of cooling as trees (see chapter 3.4), and are less common in populated urban areas, preservation of natural, open space is another strategy for keeping temperatures down. Maintaining natural areas like riparian corridors and prairies means that naturally cool surfaces are not replaced by concrete, buildings, and roads. Preservation of natural areas and open space also promotes favorable conditions for plants and animals, both of which can be negatively affected by rising temperatures. Preservation of open space can be achieved through strong zoning laws and dense urban development standards which limit urban sprawl.

4.3 Public health and 'right to cooling'

Heat is sometimes considered less of a priority than other environmental hazards because, except in the most extreme cases, it does not cause widespread, highly visible physical damage. However,

Case Study:

PORTLAND, LOS ANGELES, AND EDMOND LEGISLATION

The City of Portland, Oregon's Title 11, known colloquially as the "tree code," specifies standards for tree preservation during development. In cases when a mature tree cannot be protected from removal, developers pay a fee which goes toward planting new trees elsewhere in the city. This code also sets enforceable standards for tree density around new developments (City of Portland, 2024). Likewise, the City of Los Angeles' "Protected Trees and Shrubs Ordinance" identifies protected trees according to size and species, and requires developers who must remove protected trees to apply for a permit and pay a fee (StreetsLA, 2024). While such requirements do not fully prevent the removal of trees, they create an additional barrier for developers and generate revenue that can be used to support other aspects of urban forestry. Legislation from these two cities offers a model for OKC, though new ordinances will need to be carefully considered in light of the Dillon Rule.

- City of Portland Tree Code
- City of Los Angeles Protected Trees and Shrubs Ordinance

Closer to OKC, the City of Edmond recently adopted a tree preservation ordinance, Title 21, which requires a minimum of 20% tree canopy on all new residential properties. Per the ordinance, "when a neighborhood is designed, at least 20% of the area will be set aside for tree preservation and open space. If there are no trees to be preserved, the planting of trees will be required" (City of Edmond, 2021).

- City of Edmond Title 21 General Procedures heat kills more people in the US annually than any other environmental phenomenon, and efforts to mitigate heat have gained support as it is increasingly framed as a public health threat (Henderson et al., 2021). For example, the US Occupational Safety and Health Administration (OSHA) has released guidelines to protect workers from illness in high heat environments, and some states have laws regulating occupational heat exposure (OSHA, 2024).

Talking about and addressing heat through the lens of public health is an effective way to gain political, community, and funder buy-in. Policies and legislation which emphasize the health effects of heat may be particularly effective at improving the lives of those who are most exposed and sensitive to heat.

- Specify a heat-health policy for appropriate city departments and healthcare providers which guides outreach efforts, preparedness planning, and emergency response efforts. Such a policy would prioritize communities, localities, or socio-demographic groups which are most likely to be exposed to and/or sensitive to heat, and offer guidance on how the City and its partners can best identify and collaboratively address heat-related illness (Bolitho & Miller, 2016). Elements of this policy might favor resilience building and education; multi-pronged emergency management and response, such as training 911 dispatchers on heat-related emergencies; and the development of effective heatwave alert systems on par with systems used to notify residents of tornadoes or other emergencies (Kovats & Hajat, 2008). A policy of interdepartmental or interdisciplinary cooperation around heat should be considered, as siloed responses typically limit the effectiveness of heat-related interventions (Keith et al., 2019).
    - Position the Oklahoma County Health Department and/or adjacent public health entities as key partners in heat mitigation and adaptation efforts moving forward. Institute a policy of City departments working closely with public health agencies on future heat vulnerability assessments, plans, responses, and education campaigns.
- ‘Right to cooling’ legislation and standards provide protections for tenants, outdoor laborers, and others, and makes it easier for individuals to stay cool in high-risk environments. These rules can take several forms, for example: landlords must allow rental tenants to use portable air conditioners (Oregon State Legislature, 2022), or employers must provide outdoor laborers with shade, water, and respite in certain high heat conditions (Washington State Department of Labor & Industries, 2024). It may be necessary to advocate for legislation at the statewide level due to limitations on municipal power stemming from the Dillon Rule. Local standards could be achieved through outreach, education, and incentives as described in chapter 3.1.

Case Study:

OREGON 'RIGHT TO COOLING' LEGISLATION

In spring of 2022, the Oregon legislature passed Senate Bill 1536, also known as the 'right to cooling' bill. Oregon has had a historically temperate climate, but has recently experienced an increase in extreme heat events for which residents have been largely unprepared. Some rental tenants have previously been prohibited by landlords from installing air conditioners at home, a condition challenged by tenant rights groups and public health experts. In the interest of promoting cooling access for all, the State of Oregon passed Senate Bill 1536, limiting the ability of landlords to prohibit rental-residential air conditioning use, providing air conditioner giveaways to medically-sensitive tenants, and providing rebates for heat pump installation (Oregon State Legislature, 2022).

5: Social support

5.1 Financial and technical assistance

The City, non-profit groups, and other partners can support residents and businesses in taking proactive measures which allow them to adapt to heat and prepare for a hotter future. Upfront costs are a common barrier to individuals taking heat-adaptive action, and financially supportive services may encourage individuals to invest in efficient appliances, new insulation, and building weatherization. Beyond upgrades and retrofits, the daily costs of energy use may prove burdensome, especially to low-income residents. Therefore, support with home energy bills could be beneficial. Providing city resources for proper tree care and maintenance may also ease residents' concerns about trees and boost public acceptance of canopy expansion. Possible options for providing assistance include:

- Public subsidies or rebates for weatherization, energy upgrades, or installation of GI which offset prohibitive implementation costs (Cousins & Hill, 2021)
- Assistance with home energy bills, especially during high-heat summer months
    - While low-income OKC residents can apply for the Low Income Home Energy Assistance Program (LIHEAP), such programs are often difficult to access or not well known. City staff might work with non-profit partners to increase public awareness of such programs and guide their clients through the application process. Additionally, LIHEAP funds are typically insufficient to meet demand and supplements to the program could help those in need.
- Free tree giveaways by the City or non-profit partners to homeowners and business owners
- Free training for residents who wish to plant and steward trees or GI on their properties or in their communities
    - Training may come from a certified arborist, master gardener, GI designer, or other appropriate advisor contracted by the City.

5.2. Education and engagement

Education and awareness are important components of an effective heat mitigation and adaptation strategy. On one hand, the City and its partners must convey to the public the challenges posed by heat, the importance of heat mitigation, and the economic, social, and ecological co-benefits associated with heat mitigation interventions (Wang et al., 2021b). Without such an understanding, it is less likely that residents will respond positively to cooling measures and new expenses, or that residents will take personal initiative to mitigate heat (e.g., opt to plant and maintain a tree on one's own property). On the other hand, education is a pathway to personal heat safety awareness and adaptation. Many individuals do not understand the threat posed by heat, do not imagine that they could be susceptible to heat-related illness or mortality, and do not know the signs of serious illness (Howe et al., 2019). As temperatures rise in OKC, public health authorities and community-based organizations can make a concerted effort to educate residents about the risks posed by heat – for medically sensitive as well as seemingly healthy groups – and offer advice on activities to avoid, symptoms to look for, and measures to take when exposed to high temperatures. This includes information on avoiding heat and staying safe outdoors, indoors, and over prolonged periods of exposure to high temperatures. Potential channels to disseminate information include local news and television stations, printed materials, radio announcements, and weather-related broadcasts from local meteorologists. It is recommended that information be provided in multiple languages to reach a larger population, including those who do not speak English as a first language and miss out on English-only messaging.

Case Study:

UP WITH TREES IN TULSA

This Tulsa-based non-profit engages communities around tree planting, care, and education. The group's extensive network of volunteers has planted nearly 40,000 trees in Tulsa County, and distributed more than 200,000 seedlings. In addition to growing the urban forest through direct action and giveaways, Up With Trees provides community education on tree care topics including watering, planting, and preservation. This ensures that homeowners can apply best practices to their own trees. The organization trains 'Citizen Foresters' to become stewards of trees in their communities, with instruction on topics from "species identification and pest management, to proper planting and pruning techniques" and offers 'Tree School' to K-12 students. The success of Up With Trees depends largely on its partnership with the City of Tulsa, a major funder in addition to private donors (Up With Trees, 2024).

Engagement can inform the City's selected strategies and understanding of the problem, and cultivate community buy-in. For heat mitigation and adaptation efforts to be successful, residents must understand what the City is doing and why; must be able to connect heat-related work and challenges to their own lives, interests, and well-being; and must take some responsibility for advancing those efforts (Campbell-Arvai & Lindquist, 2021; Thorne et al., 2018). Community-based efforts can have an enormous impact on the overall heat resilience of a city, and the participation of private property owners (single family, rentals, businesses, schools) builds upon efforts made by the City. This is especially true for tree planting, given that so much urban land is privately owned and outside the purview of the City, though public buy-in also smoothes the implementation of municipal projects, new fees and taxes, and urban transformations.

5.3 Job training and volunteer corps

Getting OKC residents involved in large numbers may bolster local efforts to mitigate and adapt to extreme heat (Jerome et al., 2017). Time, labor, and resources provided by residents offer a supplement to City services which may be overstretched and lacking capacity, particularly when it comes to the maintenance of new heat-mitigating infrastructure.

- Organize a volunteer corps which can serve a variety of functions with regard to heat mitigation and adaptation. For example, Neighborhood Emergency Teams consist of volunteers who help to deploy services and perform wellness checks during a heat emergency. Youth conservation corps are invaluable as cities expand their canopies and care for green space. Neighborhood coalitions may support ongoing maintenance of GI facilities when funding is scarce. Such groups may emerge organically, though coordination by the City, a non-profit group, or other managing entity can greatly improve their efficacy and capacity.
- Job training allows residents to get involved in the work of heat mitigation, and positions individuals for future economic gain. This approach is especially valuable in underserved communities where residents may be facing the compounded stress of low incomes and high environmental exposure (heat, air pollution, flooding). Job training, combined with the creation of more 'green jobs' pertinent to heat mitigation, is a step toward building a robust network of planners and laborers who can make heat mitigation a reality. This approach also advances environmental equity goals by connecting residents with well paid jobs and building economic resilience (Lewis & Gould, 2016).
- Active training programs in the OKC region include the Community Foresters Program offered by OKC Beautiful; pruning and tree care workshops hosted by the Oklahoma Community Forestry Council; and arborist training provided by the Oklahoma Vegetation Management Association.

5.4 Emergency response plan

Working proactively toward heat adaptation and mitigation, addressing potential problems 'upstream,' is critical to building long-term resilience. However, even in the most prepared cities, extreme heat events and emergencies do occur. The City government can be ready with a robust heat emergency response protocol which directs resources and attention to high-risk areas and communities. Components of an emergency operations plan might include:

- Open public cooling centers during daytime hours (i.e., during peak afternoon heat). In prolonged heat waves when overnight temperatures remain high, overnight shelters could also be needed. City or County staff, as well as contracted non-profit partners, may be mobilized to provide staffing for government-run cooling centers and shelters.
- Offer free rides or bus fare to help vulnerable or mobility-challenged residents access cool spaces such as cooling centers, libraries, medical facilities, or public parks.
- Extend hours for air conditioned public spaces such as libraries and malls.
- Provide citywide emergency alerts in multiple languages and formats (by email, text message, phone call, on local news, online) when a heat wave is expected.
- Activate wellness checks and resources to high-risk areas such as homeless camps, mobile home parks, and affordable housing facilities. If allowable, City or County staff from agencies like homeless services, public health, emergency management, or the fire department could deploy to distribute bottled water, set up mobile cooling/misting stations, and check on city residents

Case Study:

GROUNDWORK GREEN TEAM (DENVER)

Groundwork is a national non-profit organization dedicated to sustainably managing and improving the natural environment through empowering, socially just, community- based partnerships. The Denver, CO chapter works closely with young adults through its Green Team program. This workforce development program imparts valuable training and experience in a range of green jobs and offers paid work opportunities. Green Team members' work includes building community gardens, improving parks, and educating the community about environmental issues (Groundwork Denver, 2024).

who appear unsafe outdoors. In-home wellness checks can be performed via phone calls to member listservs from low-income health plans, veterans and disability services, or other social programs. The City of OKC may also consider contracting with non-profit partners or volunteer networks to reach out to specific populations.

- Populations that are at highest risk during a heat emergency are often the most difficult to access, such as isolated adults who are not enrolled in any social services, those who are linguistically isolated (e.g., non-English speakers who cannot interpret emergency messaging), and unhoused city residents living outdoors. Non-profit partners often have specialized access that can extend the City governments' reach.

Case Study:

NEW HAMPSHIRE HEAT EMERGENCY RESPONSE PLAN

New Hampshire is one of few jurisdictions with a comprehensive Heat Emergency Response Plan. The plan includes guidelines for how to respond to heat-related illness, details of public messaging, and steps that can be taken to reduce heat stress on the local population. Strategies include opening and promoting cooling centers, extending hours for pools and beaches, offering wellness checks to those living alone, and providing safety tips for the general population as well as specific high-risk subsets (State of New Hampshire, 2014).

Given the potential for extreme heat and hazardous air pollution to co-occur in OKC, the City can consider emergency response options that address both hazards. One such strategy is to use public school buildings as summertime community refuges that provide air filtration and cooling during emergencies. This idea is relatively novel but is growing in popularity as new applications are explored nationwide (EPA, 2024b).

Case Study:

SCHOOLS AS COMMUNITY CLEANER AIR AND COOLING CENTERS

The US Environmental Protection Agency (EPA) recognizes the dual threat posed by extreme heat and poor air quality, both of which are becoming more severe as the climate changes, and both of which disproportionately affect vulnerable populations. A new grant program, funded by the American Rescue Plan, is funding four jurisdictions to develop 'cleaner air and cooling centers' within public school facilities. This includes projects in California, Oregon, Arizona, and Washington meant to transform schools into community resilience hubs where high-risk community members can seek refuge from heat and polluted air. Projects will improve indoor environmental conditions for children who attend the schools, while establishing safe spaces for others in the neighborhood. These projects target low-income, underserved areas, which typically feature higher rates of heat and air pollution, and are being done with the collaboration of community-based organizations (EPA, 2024b).

5.5 Resource giveaways

Distributing simple resources can make a significant impact on OKC residents' heat health and safety at a relatively low cost. For those who work or recreate outdoors, cooling kits including ice packs, cooling towels, sun hats, or handheld fans can provide short-term relief. In-home solutions such as blackout curtains, do-it-yourself insulation supplies (sealing tape, under-door draft stoppers), and window or portable air conditioning units can improve indoor environmental conditions. Air purifiers may help those who suffer from the combined effects of heat and air pollution, and encourage residents to open windows at night to let cooler air circulate indoors (assuming poor air quality is a cause for keeping windows closed).

5.6 Indoor recreational opportunities

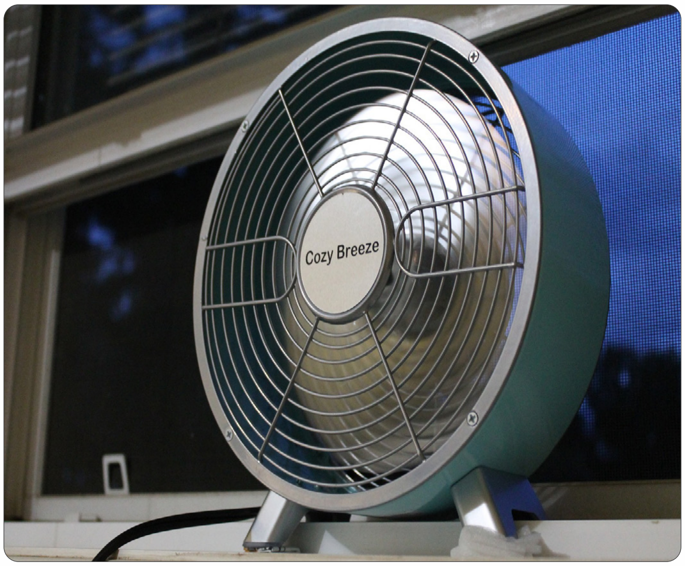
In a recent community survey, one of the primary heat-related challenges reported by residents was an inability to recreate outdoors. This was particularly pronounced for families with young children. The City can assist residents by providing (either directly, or through partnerships) more opportunities for indoor, family-friendly recreational activities. Indoor playgrounds for children may substitute for outdoor playsets which can reach unsafe temperatures in the sun. Programming in community centers, such as free movie screenings and low- to no-cost classes for kids (e.g., gymnastics, dance), offers an alternative for families who cannot spend time outdoors in the heat. If the City is unable to establish new opportunities for indoor recreation, subsidies to attend existing facilities (e.g., museums, movie theaters, aquariums, indoor play places) could be explored, especially for low-income families.

6: Household and personal adaptations

This section is dedicated to adaptive actions that individuals can take to keep themselves safe and comfortable, and their homes cool. Individuals can apply many of the City Scale heat mitigation strategies described in the previous chapters at a personalized scale. For example, homeowners can plant trees and gardens around their properties, weatherize their homes, or install their own shade structures, solar panels or green roofs. Non-homeowners can take part in public tree planting events, start or support a community garden, or volunteer to steward trees and other green infrastructure assets in their neighborhoods. The accumulation of personal actions like these can have a real impact on outdoor urban temperatures beyond a single residence. Residents can also access household-specific solutions including airflow maximization, air conditioning and dehumidification, insulation and venting, indoor shading, and self cooling which will improve personal comfort on hot days.

6.1 Airflow maximization: strategic use of fans and windows

Maximizing airflow is one of the most effective ways to keep your home cool and does not require the use of energy-intensive air conditioners. It can often be achieved passively by opening windows and doors when there is a breeze or wind outside. During the hottest part of the day, it is better to open windows near shaded spots with cooler outdoor air, and avoid opening windows that receive high sun exposure (US Department of Energy, 2001). You can enhance airflow by adding fans in combination with open windows or air conditioning.



- Open windows overnight and in the early morning hours when air is coolest. You can also set up fans at your windows, pointing inwards, during these times. This will allow the fans to pull cool air from outside and circulate it in your home.
- Close windows during the day and early evening when outdoor temperatures are highest. This will trap cool air inside and prevent warm air from entering. Avoid using window fans to blow air into your home when outdoor temperatures are higher than indoor temperatures.
- Once outdoor temperatures cool down, you can create cross ventilation to pull cool air in and push hot air out. Do this by placing a window fan at one side of your house, pointing inwards – this fan will pull in cooler air from outside. At the same time, set up a second fan at the other side of your house, pointing outwards – this fan will remove hot air that is already in your home (US Department of Energy, 2001).
- Ceiling fans are highly effective at cooling indoor spaces, especially when combined with air conditioning. Ceiling fans should be run counterclockwise in the summer to prevent warm air being pushed down. If running a ceiling fan in combination with an air conditioner, you can set the thermostat around 4 degrees higher without experiencing a decrease in comfort (US Department of Energy, 2024).

- Whole-house fans are costlier to install than ceiling or portable fans, but can efficiently remove hot air from your home. Other options to promote targeted hot air removal and dehumidification include exhaust fans in the kitchen and bathroom (US Department of Energy, 2001).

6.2 Air conditioning and dehumidification

Electrical air conditioners (AC) are the most commonly-used cooling strategy worldwide, but are not a sustainable solution to extreme heat. While cooling indoor environments, they actually contribute heat to the outdoor environment, and widespread use of AC can overload local power grids resulting in blackouts. However, in the short term, air conditioners are a critical tool. They improve indoor thermal comfort and safety by reducing air temperature and humidity (Jay et al., 2021). It is recommended that residents have at least one cool room in their home which remains under 80°F (Jay et al., 2021; Oregon State Legislature, 2022). Heat pumps are an alternative to conventional ACs which are more sustainable and energy efficient, and are growing in popularity. Heat pumps, which come in both centralized and portable forms, should be prioritized over conventional AC when possible.

For residents with a mechanical cooling system: In the absence of a central AC or heat pump, cooling and dehumidification can be achieved by using a portable or window AC unit. Close doors and other windows in the room with the portable unit to keep cold air inside, and ensure that the AC unit or exhaust pipe fits snugly in your window to prevent the loss of cooled air.

For residents without a mechanical cooling system: Without an AC or heat pump, you can increase your comfort and safety by focusing on dehumidification. Portable dehumidifiers are typically less expensive to purchase and operate than air conditioners. By removing moisture from the air, you can increase your body's ability to cool itself naturally through sweating, even in higher temperatures. Running fans and maximizing airflow (see section 6.1) can also help you reduce humidity and cool your space.

Note: "Swamp coolers" (also known as evaporative air coolers) are a type of do-it-yourself air cooler that relies on the evaporation of chilled water. These are not recommended for use in humid climates because they add moisture to the air (Sustainable Energy for All, 2024).

6.3 Insulation and venting

A well-insulated house is more able to keep cool air in and hot air out when you use the cooling strategies described above (windows, fans, air conditioning). Permanent upgrades to your home can be expensive initially, but save you money in the long run by reducing your energy use for both cooling and heating. For income-qualifying households (renters and homeowners), funding is available through the State's Weatherization Assistance Program for weatherization and utility assistance.

Options for improving insulation:

- Install new insulation in your attic and/or under your roof. The roof is an entry point for a lot of solar radiation and heat into your home.

- Install new insulation in walls, particularly those which receive the most sun exposure during the day.
- Replace windows and doors to ensure a snug fit and reduce draftiness.

The effects of good insulation are magnified by good ventilation. This can be achieved through some actions already described, including the use of open windows and doors, exhaust fans, window fans, and central air conditioning. The idea with all ventilation is to keep air moving through your home and prevent hot air from becoming trapped inside.

- Installing a ventilation system in your attic or under-roof crawl space can help to keep hot air from entering your living space. However, it is better to prevent hot air from entering through the roof in the first place, which can be achieved with proper insulation, a reflective roof, or a green roof.
- Whole-house fan systems are a type of in-built, mechanical ventilation which are highly effective and energy efficient, and may alleviate the need to use electrical air conditioners for much of the summer (US Department of Energy, 2001; Zhang et al., 2021).

6.4 Shades, overhangs, and window films

Preventing solar radiation from hitting your home is a simple way to reduce indoor temperatures. This can be achieved by increasing the amount of shading on your property, whether through trees, tall shrubs, or manmade shade structures such as awnings, eaves, cantilevers, and similar overhangs. Installing overhangs or other shade structures around your home will keep your indoor space cooler, and provide cooler outdoor air that you can ventilate inside as needed (see section 6.1). Overhangs and shading on the south side of your building will have the greatest potential impact as this is the side that typically receives the most sun exposure. Detached shade structures will not cool your home but can make it more pleasant to spend time outdoors in the heat.

You can keep indoor spaces cool by having blinds down and curtains closed; this is especially important when your windows are receiving direct sunlight, such as east facing windows in the morning and west facing windows at sunset. South and southwest facing windows should be covered throughout the day (Jay et al., 2021). Blackout curtains are particularly effective at reducing indoor temperatures as they allow little to no sunlight to pass through. Thinner fabrics and slatted blinds are less effective for this purpose. Heat resistant window films are an affordable option that can be installed by residents, though these are not as easily removed as curtains and blinds when not in use.

6.5 Self cooling and rest

If you are unable to effectively cool your home or workplace, or if you are outdoors in the heat for extended periods of time, you are potentially vulnerable to heat-related stress and illness. Children under five years old, adults over 65, pregnant women, and those with certain chronic health conditions are at highest risk for illness, but even seemingly healthy adults can be susceptible. Outdoor laborers and athletes are vulnerable to heat stroke and stress resulting from sustained exertion in outdoor heat (CDC, 2024b). It is important to limit physical activity and exertion in the heat (indoor and outdoor) when possible, and rest when you feel overheated. Overexertion in the heat can be particularly dangerous on ozone alert days when air pollution reaches unhealthy levels. Below are several strategies for self cooling to improve your comfort and bring down your internal body temperature.

- Drink cold water to stay cool. Drink water, tea, or other beverages at any temperature to stay hydrated during periods of heavy sweating.
- Take a cold bath or shower, or immerse your feet in cold water.
- Find a cool place to swim or play in water (e.g., a natural body of water, swimming pool, or waterpark).
- Splash water on your skin and dry in front of a fan.
- Place wet towels in the freezer and drape them over your head or body once chilled.
- Hold ice cubes or a chilled glass against pulse points on your wrists and throat, or on the back of your neck.
- Find shade or an air conditioned indoor space.
- Protect your skin from direct sun exposure with a hat, sunglasses, lightweight clothing that covers arms and legs, and/or sunblock. Ideally, this protection will occur before you become overheated.

Note: If you are experiencing symptoms of heat stroke, please seek medical attention. See the first linked resource in section *6.6 Resources: heat related illness and safety*, titled “Signs and Symptoms of Heat Related Illness” for more information about heat stroke symptoms.

6.6 Resources: heat related illness and safety

- Signs and Symptoms of Heat Related Illness (poster)
  https://www.cdc.gov/disasters/extremeheat/warning.html
- Avoid, Spot, Treat: Heat Stroke & Heat (infographic)
  https://www.cdc.gov/cpr/infographics/ast-heat.htm
- Heat-Related Illness and First Aid:
  https://www.cdc.gov/niosh/topics/heatstress/heatrelillness.html
- General Overview: Heat Vulnerability and Illness (includes information on humidity)
  https://my.clevelandclinic.org/health/diseases/16425-heat-illness
- Occupational Safety: Working in Indoor and Outdoor Heat Environments
  https://www.osha.gov/heat-exposure
- Protecting Disproportionately Affected Populations from Extreme Heat
  https://www.cdc.gov/disasters/extremeheat/specificgroups.html

Summary of Interventions

	Intervention	Details
City Scale Strategies	Trees	Distribute trees throughout densely populated urban areas
		Aim for canopy coverage of 30-40%
		Leafy, broad canopy trees are most effective for shading
		Prioritize native species
	Building Codes	Incentive cool roofs (green or reflective) and energy efficiency in new developments
		Consider opportunities to retrofit existing structures
	Transportation Infrastructure	Apply "Complete Streets" principles to improve pedestrian safety and comfort
		Increase opportunities for active transportation to decrease air pollution and heat
	Non-Vegetative Shading	Prioritize busy commuter routes for permanent or temporary shade structures
		Aim for at least 30% shade coverage along transportation paths; focus on resting or waiting points such as bus stops and benches
		Pergolas, canopies, and man-made shade coverings can provide relief from the heat comparable to tree shade, though do not come with the environmental co-benefits of trees

City Scale Strategies	Green & Blue Infrastructure	Green walls, green roofs, permeable pavements, and bioswales offer heat mitigation and stormwater management
		Open, vegetated space is more cooling than concrete but less cooling than tree shade; open space is most cooling when configured in compact, simple shapes; cooling function is improved when trees are distributed throughout
		Green roofs do not impact pedestrian-level temperature but can reduce temperature inside a building; aim for hardy, low-lying, native vegetation that can survive on rainwater and in direct sunlight
		Trees and vegetation are most effective for cooling when located near a body of water
		Blue infrastructure solutions include flood control infrastructure like bioswales as well as drinking fountains and/or water bottle refill stations, misting stations, or splash pads
	Energy	Weatherize, electrify, and update insulation in existing structures via incentives; Establish efficiency standards for new construction
		Non-conventional models for energy sharing include district cooling and solar microgrids
	Funding	Sources of funding include federal grants, State grants, bonds, and donations
	Tree & Open Space Preservation	Establish tree preservation or protection ordinances that limit tree removal during construction or for other purposes, and/or require minimum canopy coverage on new developments
		Implement zoning laws that favor density and limit urban sprawl into natural, open spaces

City Scale Strategies	Public Health & 'Right to Cooling'	Public health framing is effective when seeking buy-in for heat-related projects
		'Right to Cooling' legislation requires that new residential developments provide for at least one cool room in every home, and that employers provide safe working conditions for employees during hight heat
	Financial & Technical Assistance	Offer subsidies or rebates for energy efficiency upgrades and home or building weatherization
		Assist homeowners with energy bills related to cooling; expand upon programs like LIHEAP
		Provide free training to homeowners on tree planting and care
	Education & Engagement	Educate residents about heat risk, who is at risk, what symptoms to look out for, and how to stay safe
		Engage with residents to explain the urban heat island effect and why the City wants to take certain actions to mitigate it; get public buy-in for projects
	Job Training & Volunteer Corps	Organize volunteers to assist with tree planting, tree and natural area maintenance, and other functions when staff capacity is limited
		Job training gets locals involved in green jobs, builds economic resilience, and expands the workforce
	Emergency Response Plan	Open cooling centers; provide free bus fare or rides to cool places; extend hours at air conditioned public places; provide citywide alerts in multiple languages; active wellness check to high-risk populations
		Develop a formal Heat Emergency Response Plan with roles and responsibilities
	Resource Giveaways	Cooling kits, bottled water, fans, and ice packs provide short-term relief while giveaways of shade curtains, portable AC units or heat pumps, and dehumidifiers could help with indoor heat long term
	Indoor Recreational Opportunities	Increase access to family-friendly indoor activities during high heat; reduce cost barriers for low-income families

Household Scale Strategies	Air Flow Maximization	Open windows overnight and close them during the day; use fans to move cool outside air and/or air conditioned indoor air around the home
	Air Conditioning & Dehumidification	Prioritize energy efficient heat pumps over portable or central AC; in the absence of mechanical cooling, improve indoor comfort with a dehumidifier; avoid swamp coolers/evaporative coolers in a humid environment
	Insulation & Venting	Upgrade insulation in roofs and walls; install a whole house fan or ventilation system in the attic; replace windows and doors for a better seal
	Shades, Overhangs & Window Film	Add shade outside to reduce solar radiation using tall vegetation or manmade shade structures; focus shade on the south side of a building; cover windows with blackout curtains, especially south/southwest windows
	Self-Cooling & Rest	Avoid outdoor exertion in the heat, especially on ozone alert days; cool off with water, ice, or air conditioning; seek help for symptoms of heat stroke

References

Anguelovski, I., Connolly, J. J. T., Cole, H., Garcia-Lamarca, M., Triguero-Mas, M., Baró, F., … Minaya, J. M. (2022). Green gentrification in European and North American cities. Nature Communications, 13(1), 3816. https://doi.org/10.1038/s41467-022-31572-1

Antoszewski, P., Świerk, D., & Krzyżaniak, M. (2020). Statistical Review of Quality Parameters of Blue-Green Infrastructure Elements Important in Mitigating the Effect of the Urban Heat Island in the Temperate Climate (C) Zone. International Journal of Environmental Research and Public Health, 17(19), 7093. https://doi.org/10.3390/ijerph17197093

Arbor Day Foundation (2017). How to write a municipal tree ordinance. Tree City USA Bulletin. No. 9. https://www.arborday.org/trees/bulletins/coordinators/resources/pdfs/009.pdf

Arbor Day Foundation (n.d.). The Right Tree for the Right Place. Tree City USA Bulletin No 4. https://www.arborday.org/trees/bulletins/coordinators/resources/pdfs/004.pdf

Arlington County (2020). County Board Agenda Item. Updates to the Green Building Incentive Policy for Site Plan Projects. https://www.arlingtonva.us/files/sharedassets/public/Environment/Documents/Board_Report_35-FINAL.pdf

Baietti, A., Shlyakhtenko, A., La Rocca, R., & Patel, U D. (2012). Green Infrastructure Finance: Leading Initiatives and Research. World Bank Study; Washington, DC. https://openknowledge.worldbank.org/handle/10986/13142

Berisha, V., Hondula, D., Roach, M., White, J. R., McKinney, B., Bentz, D., … Goodin, K. (2017). Assessing Adaptation Strategies for Extreme Heat: A Public Health Evaluation of Cooling Centers in Maricopa County, Arizona. Weather, Climate, and Society, 9(1), 71–80. https://doi.org/10.1175/WCAS-D-16-0033.1

Bloch, S. (2019). The Problem With 'Cool Pavements': They Make People Hot. Bloomberg. https://www.bloomberg.com/news/articles/2019-10-03/reflective-pavement-may-be-less-cool-than-it-seems

Bolitho, A., & Miller, F. (2017). Heat as emergency, heat as chronic stress: Policy and institutional responses to vulnerability to extreme heat. Local Environment, 22(6), 682–698. https://doi.org/10.1080/13549839.2016.1254169

Britannica (2024). Humid subtropical climate climatology. Earth Sciences. https://www.britannica.com/science/humid-subtropical-climate

Burke, M., González, F., Baylis, P., Heft-Neal, S., Baysan, C., Basu, S., & Hsiang, S. (2018). Higher temperatures increase suicide rates in the United States and Mexico. Nature Climate Change, 8(8), 723–729. https://doi.org/10.1038/s41558-018-0222-x

Campbell-Arvai, V., & Lindquist, M. (2021). From the ground up: Using structured community engagement to identify objectives for urban green infrastructure planning. Urban Forestry & Urban Greening, 59, 127013. https://doi.org/10.1016/j.ufug.2021.127013

CAPA Strategies (2024). Open Science Framework. Heat Watch Mapping Results Database. https://osf.io/9neka/

Casati, B., Yagouti, A., & Chaumont, D. (2013). Regional Climate Projections of Extreme Heat Events in Nine Pilot Canadian Communities for Public Health Planning. Journal of Applied Meteorology and Climatology, 52(12), 2669–2698. https://doi.org/10.1175/JAMC-D-12-0341.1

CDC (2024a). Heat and People with Chronic Medical Conditions. Natural Disasters and Severe Weather. https://www.cdc.gov/disasters/extremeheat/medical.html#:~:text=Conditions%20like%20heart%20disease%2C%20mental,to%20retain%20more%20body%20heat.

CDC (2024b). Protecting Disproportionately Affected Populations from Extreme Heat. Natural Disasters and Severe Weather. https://www.cdc.gov/disasters/extremeheat/specificgroups.html

City of Boston (2024). Healthy and Green Retrofit Pilot Program. Housing. https://www.boston.gov/housing/healthy-and-green-retrofit-pilot-program

City of Charleston (2021). Climate Action Plan. https://www.charleston-sc.gov/DocumentCenter/View/29763/Final-Climate-Action-Plan-May-2021-spreads

City of Dallas (2020). Dallas Climate Action. https://www.dallasclimateaction.com/cecap

City of Edmond (2021). Edmond City Council Adopts Tree Preservation Ordinances. https://www.edmondok.gov/1644/Tree-Preservation-Ordinances-Adopted#:~:text=New%20residential%20developments%20will%20be,preservation%20in%20new%20residential%20developments

City of Kansas City (2022). Climate Protection & Resiliency Plan. https://www.kcmo.gov/home/showpublisheddocument/9912/638112897582470000

City of Portland (2024). Tree Code Information Guide. https://www.portland.gov/trees/trees-development/documents/tree-code-information-guide-tree-requirements-development/download

City of Norman (2020). Landscape Maintenance and Replacement Bond. https://www.normanok.gov/sites/default/files/documents/2020-05/Landscape%20Maintenance%20Bond.pdf

City of Tulsa (2024). Stormwater Fee & Funding. Flood Control. https://www.cityoftulsa.org/government/departments/water-and-sewer/flood-control/stormwater-fee-and-funding/

Climate-Data.org (2024). Climate Oklahoma City (United States of America). https://en.climate-data.org/north-america/united-states-of-america/oklahoma/oklahoma-city-718571/

Climable (2024). Chinatown Microgrid Project. https://climable.org/chinatown-microgrid

Cohen-Shacham, E., Walters, G., Janzen, C., & Maginnis, S. (eds.) (2016). Nature-based Solutions to address global societal challenges. Gland, Switzerland: IUCN. https://serval.unil.ch/resource/serval:BIB_93FD38C8836B.P001/REF

Coris, E. E., Ramirez, A. M., & Van Durme, D. J. (2004). Heat Illness in Athletes: The Dangerous Combination of Heat, Humidity and Exercise. Sports Medicine, 34(1), 9–16. https://doi.org/10.2165/00007256-200434010-00002

Cousins, J. J., & Hill, D. T. (2021). Green infrastructure, stormwater, and the financialization of municipal environmental governance. Journal of Environmental Policy & Planning, 23(5), 581–598. https://doi.org/10.1080/1523908X.2021.1893164

Daemei, A. B., Shafiee, E., Chitgar, A. A., & Asadi, S. (2021). Investigating the thermal performance of green wall: Experimental analysis, deep learning model, and simulation studies in a humid climate. Building and Environment, 205, 108201. https://doi.org/10.1016/j.buildenv.2021.108201

Davey Resource Group (2009). City of Portland, OR: Initial Assessment of the Costs of Managing Street Trees as a Public Asset. https://www.portland.gov/trees/documents/initial-assessment-costs-managing-street-trees-public-asset/download

deGuzman, E., Malarich, R., Large, L., & Danoff-Burg, S. (2018). Inspiring Resident Engagement: Identifying Street Tree Stewardship Participation Strategies In Environmental Justice Communities Using A Community-Based Social Marketing Approach. Arboriculture & Urban Forestry, 44(6), 291–306. https://www.ioes.ucla.edu/wp-content/uploads/291_306_AUFNov2018.pdf

Droste, N., Schröter-Schlaack, C., Hansjürgens, B., & Zimmermann, H. (2017). Implementing Nature-Based Solutions in Urban Areas: Financing and Governance Aspects. In N. Kabisch, H. Korn, J. Stadler, & A. Bonn (Eds.), Nature-Based Solutions to Climate Change Adaptation in Urban Areas (pp. 307–321). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-56091-5_18

Environmental Protection Agency (EPA) (2024a). Using Green Roofs to Reduce Heat Islands. Heat Islands. https://www.epa.gov/heatislands/using-green-roofs-reduce-heat-islands

Environmental Protection Agency (EPA) (2024b). Schools as Community Cleaner Air and Cooling Centers. American Rescue Plan. https://www.epa.gov/arp/schools-community-cleaner-air-and-cooling-centers

Gastelum, D. (2022). The Role of Microgrids in Building Climate Resilience in Boston's Frontline Communities. ClimateXChange. https://climate-xchange.org/2022/01/07/the-role-of-microgrids-in-building-climate-resilience-in-bostons-frontline-communities/

Gellerman, B. & Greene, D. (2021). Chelsea and Chinatown are building microgrids to solve big energy, climate challenges. WBUR local coverage. https://www.wbur.org/news/2021/11/24/massachusetts-microgrids-energy-resilience

Getter, K.L. (2015). Selecting Plants for Extensive Green Roofs in the United States. Michigan State University Extension. https://www.canr.msu.edu/resources/selecting_plants_for_extensive_green_roofs_in_the_united_states_e3047

Glazener, A., & Khreis, H. (2019). Transforming Our Cities: Best Practices Towards Clean Air and Active Transportation. Current Environmental Health Reports, 6(1), 22–37. https://doi.org/10.1007/s40572-019-0228-1

Goodwin, L. (2019). Community Microgrids: Four Examples of Local Energy that Improves Lives. Microgrid Knowledge. https://www.microgridknowledge.com/google-news-feed/article/11429230/community-microgrids-four-examples-of-local-energy-that-improves-lives

Gould, K., & Lewis, T. (2016). Green Gentrification (0 ed.). Routledge. https://doi.org/10.4324/9781315687322

Gronlund, C. J. (2014). Racial and Socioeconomic Disparities in Heat-Related Health Effects and Their Mechanisms: A Review. Current Epidemiology Reports, 1(3), 165–173. https://doi.org/10.1007/s40471-014-0014-4

Groundwork Denver (2024). Green Team. Programs. https://groundworkcolorado.org/programs/youth/groundwork-denvers-green-team/

Hellman, D., deGuzman, E., O'Leary, R., Yu, K., Chen, C., & Shandas, V. (2024). Los Angeles Urban Forest Equity: Assessment, Tools, and Recommendations. UCLA Luskin Center for Innovation. https://escholarship.org/uc/item/1gt5f9x2

Henderson, S. B., McLean, K. E., Lee, M., & Kosatsky, T. (2021). Extreme heat events are public health emergencies. BJ Medical Journal, 63(9), 366–367. https://bcmj.org/bccdc/extreme-heat-events-are-public-health-emergencies

Heynen, N. C. (2003). The Scalar Production of Injustice within the Urban Forest. Antipode, 35(5), 980–998. https://doi.org/10.1111/j.1467-8330.2003.00367.x

Howe, P. D., Marlon, J. R., Wang, X., & Leiserowitz, A. (2019). Public perceptions of the health risks of extreme heat across US states, counties, and neighborhoods. Proceedings of the National Academy of Sciences, 116(14), 6743–6748. https://doi.org/10.1073/pnas.1813145116

Inayat, A., & Raza, M. (2019). District cooling system via renewable energy sources: A review. Renewable and Sustainable Energy Reviews, 107, 360–373. https://doi.org/10.1016/j.rser.2019.03.023

Jaluzot, A. & Ferranti. E. (2019). First Steps in Valuing Trees and Green Infrastructure. Trees and Design Action Group (TDAG): London. http://epapers.bham.ac.uk/3226/

Jay, O., Capon, A., Berry, P., Broderick, C., de Dear, R., Havenith, G., … Ebi, K. L. (2021). Reducing the health effects of hot weather and heat extremes: From personal cooling strategies to green cities. The Lancet, 398(10301), 709–724. https://doi.org/10.1016/S0140-6736(21)01209-5

Jerome, G., Mell, I., & Shaw, D. (2017). Re-defining the characteristics of environmental volunteering: Creating a typology of community-scale green infrastructure. Environmental Research, 158, 399–408. https://doi.org/10.1016/j.envres.2017.05.037

Jordan, S. W., & Ivey, S. (2021). Complete Streets: Promises and Proof. Journal of Urban Planning and Development, 147(2), 04021011. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000684

Karner, A., Hondula, D. M., & Vanos, J. K. (2015). Heat exposure during non-motorized travel: Implications for transportation policy under climate change. Journal of Transport & Health, 2(4), 451–459. https://doi.org/10.1016/j.jth.2015.10.001

Keith, L., Meerow, S., & Wagner, T. (2019). Planning for Extreme Heat: A Review. Journal of Extreme Events, 06(03n04), 2050003. https://doi.org/10.1142/S2345737620500037

Koeppen-Geiger (2024). World Map Of The Köppen-Geiger Climate Classification Updated. http://koeppen-geiger.vu-wien.ac.at/present.htm

Kong, L., Lau, K. K.-L., Yuan, C., Chen, Y., Xu, Y., Ren, C., & Ng, E. (2017). Regulation of outdoor thermal comfort by trees in Hong Kong. Sustainable Cities and Society, 31, 12–25. https://doi.org/10.1016/j.scs.2017.01.018
Kovats, R. S., & Hajat, S. (2008). Heat Stress and Public Health: A Critical Review. Annual Review of Public Health, 29(1), 41–55. https://doi.org/10.1146/annurev.publhealth.29.020907.090843

Lamond, J., & Everett, G. (2019). Sustainable Blue-Green Infrastructure: A social practice approach to understanding community preferences and stewardship. Landscape and Urban Planning, 191, 103639. https://doi.org/10.1016/j.landurbplan.2019.103639

Lanza, K., & Durand, C. P. (2021). Heat-Moderating Effects of Bus Stop Shelters and Tree Shade on Public Transport Ridership. International Journal of Environmental Research and Public Health, 18(2), 463. https://doi.org/10.3390/ijerph18020463

Li, X., Zhou, W., Ouyang, Z., Xu, W., & Zheng, H. (2012). Spatial pattern of greenspace affects land surface temperature: Evidence from the heavily urbanized Beijing metropolitan area, China. Landscape Ecology, 27(6), 887–898. https://doi.org/10.1007/s10980-012-9731-6

Liao, K.-H., Deng, S., & Tan, P. Y. (2017). Blue-Green Infrastructure: New Frontier for Sustainable Urban Stormwater Management. In P. Y. Tan & C. Y. Jim (Eds.), Greening Cities (pp. 203–226). Singapore: Springer Singapore. https://doi.org/10.1007/978-981-10-4113-6_10

Makri, A., & Stilianakis, N. I. (2008). Vulnerability to air pollution health effects. International Journal of Hygiene and Environmental Health, 211(3–4), 326–336. https://doi.org/10.1016/j.ijheh.2007.06.005

Marsh, J. (2023). Behind-the-meter: What you need to know. Energy Sage. https://www.energysage.com/electricity/behind-the-meter-overview/

Mell, I. (2018). Financing the future of green infrastructure planning: Alternatives and opportunities in the UK. Landscape Research, 43(6), 751–768. https://doi.org/10.1080/01426397.2017.1390079

Miles-Novelo, A., & Anderson, C. A. (2019). Climate Change and Psychology: Effects of Rapid Global Warming on Violence and Aggression. Current Climate Change Reports, 5(1), 36–46. https://doi.org/10.1007/s40641-019-00121-2

National Park Service (2022). Green Roofs on Historic Buildings: Plants for Green Roofs. https://www.nps.gov/articles/000/green-roofs-on-historic-buildings-plants-for-green-roofs.htm#:~:text=Plants%20for%20extensive%20green%20roofs%20should%20have%20low%20growth%20height,conditions%20and%20minimize%20water%20loss.

National Weather Service (2024). Weather Fatalities 2022. Weather Related Fatality and Injury Statistics. https://www.weather.gov/hazstat/

National Wildlife Federation (2024). How trees make a difference. https://www.nwf.org/Trees-for-Wildlife/About/Trees-Make-a-Difference#:~:text=Trees%20lower%20air%20temperatures%20and,transpiration%2C%20has%20a%20cooling%20effect.

Ng, E., Chen, L., Wang, Y., & Yuan, C. (2012). A study on the cooling effects of greening in a high-density city: An experience from Hong Kong. Building and Environment, 47, 256–271. https://doi.org/10.1016/j.buildenv.2011.07.014

Oklahoma City (2024). Article XI. - Landscaping and Screening Regulations. https://library.municode.com/ok/oklahoma_city/codes/code_of_ordinances?nodeId=OKMUCO2020_CH59ZOPLCO_ARTXILASCRE

Onishi, A., Cao, X., Ito, T., Shi, F., & Imura, H. (2010). Evaluating the potential for urban heat-island mitigation by greening parking lots. Urban Forestry & Urban Greening, 9(4), 323–332. https://doi.org/10.1016/j.ufug.2010.06.002

Oregon State Legislature (2022). Senate Bill 1536. https://olis.oregonlegislature.gov/liz/2022R1/Downloads/MeasureDocument/SB1536/Enrolled

OSHA (2024). Overview: Working in Outdoor and Indoor Heat Environments. https://www.osha.gov/heat-exposure

Ouyang, W., Morakinyo, T. E., Ren, C., & Ng, E. (2020). The cooling efficiency of variable greenery coverage ratios in different urban densities: A study in a subtropical climate. Building and Environment, 174, 106772. https://doi.org/10.1016/j.buildenv.2020.106772

Ouyang, W., Ren, G., Tan, Z, Li, Y., & Ren, C. (2023). Natural Shading vs. Artificial Shading: A Comparative Analysis on Their Cooling Efficacy in Subtropical Outdoor Environments. SSRN. http://dx.doi.org/10.2139/ssrn.4669730

Pew (2019). Issue Brief. Norfolk's Revised Zoning Ordinance Aims to Improve Flood Resilience. https://www.pewtrusts.org/en/research-and-analysis/issue-briefs/2019/11/norfolks-revised-zoning-ordinance-aims-to-improve-flood-resilience

Pincetl, S., Gillespie, T., Pataki, D. E., Saatchi, S., & Saphores, J.-D. (2013). Urban tree planting programs, function or fashion? Los Angeles and urban tree planting campaigns. GeoJournal, 78(3), 475–493. https://doi.org/10.1007/s10708-012-9446-x

Qiu, G., Li, H., Zhang, Q., Chen, W., Liang, X., & Li, X. (2013). Effects of Evapotranspiration on Mitigation of Urban Temperature by Vegetation and Urban Agriculture. Journal of Integrative Agriculture, 12(8), 1307–1315. https://doi.org/10.1016/S2095-3119(13)60543-2

Ran, J., & Tang, M. (2018). Passive cooling of the green roofs combined with night-time ventilation and walls insulation in hot and humid regions. Sustainable Cities and Society, 38, 466–475. https://doi.org/10.1016/j.scs.2018.01.027

Raymond, C., Matthews, T., & Horton, R. M. (2020). The emergence of heat and humidity too severe for human tolerance. Science Advances, 6(19), eaaw1838. https://doi.org/10.1126/sciadv.aaw1838

Riedman, E., Roman, L. A., Pearsall, H., Maslin, M., Ifill, T., & Dentice, D. (2022). Why don't people plant trees? Uncovering barriers to participation in urban tree planting initiatives. Urban Forestry & Urban Greening, 73, 127597. https://doi.org/10.1016/j.ufug.2022.127597

Saber, H. H. (2022). Hygrothermal performance of cool roofs with reflective coating material subjected to hot, humid and dusty climate. Journal of Building Physics, 45(4), 457–481. https://doi.org/10.1177/17442591211001408

Shih, W. (2017). The cooling effect of green infrastructure on surrounding built environments in a sub-tropical climate: A case study in Taipei metropolis. Landscape Research, 42(5), 558–573. https://doi.org/10.1080/01426397.2016.1235684

Smart Growth America (2019). The Best Complete Streets Policies of 2018. https://smartgrowthamerica.org/tag/complete-streets-case-studies/page/2/

South Central Climate Adaptation Science Center (2020). Climate Projections for Oklahoma City. https://www.okc.gov/home/showpublisheddocument/20783/637438052394700000

State of New Hampshire (2014). Excessive Heat Emergency Response Plan. Department of Health and Human Services. https://www.dhhs.nh.gov/sites/g/files/ehbemt476/files/documents/2021-11/nh-excessive-heat-plan-2014.pdf

State of Oklahoma (2020). Title 165: Corporation Commission Chapter 35. Electric Utility Rules. https://oklahoma.gov/content/dam/ok/en/occ/documents/ajls/jls-courts/rules/2020/current-rules/chapter-35-electric-utility-rules-effective-2020-09-15.pdf

Stecker, S. (2014). E&E: Old trees store more carbon, more quickly, than younger trees. Pacific Forest Trust. https://www.pacificforest.org/ee-old-trees-store-more-carbon-more-quickly-than-younger-trees/

Stone, B., Mallen, E., Rajput, M., Gronlund, C. J., Broadbent, A. M., Krayenhoff, E. S., … Georgescu, M. (2021). Compound Climate and Infrastructure Events: How Electrical Grid Failure Alters Heat Wave Risk. Environmental Science & Technology, 55(10), 6957–6964. https://doi.org/10.1021/acs.est.1c00024

StreetsLA (2024). Ordinance No. 186873 (Protected Trees and Shrubs Ordinance). https://streetsla.lacity.org/sites/default/files/protected_tree_ordinance.pdf

Sustainable Energy for All (2024). Sustainable Cooling Solutions. https://thisiscool.seforall.org/solutions#solutions

Taha, H. (1997). Urban climates and heat islands: Albedo, evapotranspiration, and anthropogenic heat. Energy and Buildings, 25(2), 99–103. https://doi.org/10.1016/S0378-7788(96)00999-1

Think Microgrid (2024). Types of Microgrids. https://www.thinkmicrogrid.org/microgrid-types

Thorne, C. R., Lawson, E. C., Ozawa, C., Hamlin, S. L., & Smith, L. A. (2018). Overcoming uncertainty and barriers to adoption of Blue-Green Infrastructure for urban flood risk management. Journal of Flood Risk Management, 11(S2). https://doi.org/10.1111/jfr3.12218

Treekeepers of Washington County (2024). Benefits of trees. https://www.treekeeperswc.org/tree-benefits-information

United Nations Environment Programme (2021). Beating the Heat: A Sustainable Cooling Handbook for Cities. https://www.unep.org/resources/report/beating-heat-sustainable-cooling-handbook-cities

University of Florida (2020). Establishment period for trees. Landscape plants. https://hort.ifas.ufl.edu/woody/establishment-period.shtml#:~:text=Trees%20provided%20with%20regular%20irrigation,roots%20in%20the%20landscape%20soil.

University of Oklahoma Institute for Quality Communities (2015). Biking, Walking, and Transit Use Across the US (2013). https://iqc.ou.edu/2015/01/27/modeshare2013/

Up With Trees (2024). https://upwithtrees.org/

US Department of Energy (2001). Cooling your home with fans and ventilation. Energy Efficiency and Renewable Energy Clearinghouse. https://www.nrel.gov/docs/fy01osti/29513.pdf

US Department of Energy (2015). Getting it right: Weatherization and energy efficiency are good investments. Office of Energy Efficiency & Renewable Energy. https://www.energy.gov/eere/articles/getting-it-right-weatherization-and-energy-efficiency-are-good-investments

US Department of Energy (2024). Fans for cooling. Energy Saver. https://www.energy.gov/energysaver/fans-cooling

Wang, C., Wang, Z.-H., Kaloush, K. E., & Shacat, J. (2021). Perceptions of urban heat island mitigation and implementation strategies: Survey and gap analysis. Sustainable Cities and Society, 66, 102687. https://doi.org/10.1016/j.scs.2020.102687

Wang, Y., Ni, Z., Hu, M., Chen, S., & Xia, B. (2021). A practical approach of urban green infrastructure planning to mitigate urban overheating: A case study of Guangzhou. Journal of Cleaner Production, 287, 124995. https://doi.org/10.1016/j.jclepro.2020.124995

Washington State Department of Labor & Industries (2024). Be heat smart! Your outdoor heat safety program. Safety & Health. https://lni.wa.gov/safety-health/safety-training-materials/workshops-events/beheatsmart

Watanabe, S., Nagano, K., Ishii, J., & Horikoshi, T. (2014). Evaluation of outdoor thermal comfort in sunlight, building shade, and pergola shade during summer in a humid subtropical region. Building and Environment, 82, 556-565. https://doi.org/10.1016/j.buildenv.2014.10.002

Weather Underground (2024). Oklahoma City, OK weather history. https://www.wunderground.com/history/daily/us/ok/oklahoma-city/KOKC

Widney, S., Fischer, B., & Vogt, J. (2016). Tree Mortality Undercuts Ability of Tree-Planting Programs to Provide Benefits: Results of a Three-City Study. Forests, 7(12), 65. https://doi.org/10.3390/f7030065

Yu, Z., Guo, X., Jørgensen, G., & Vejre, H. (2017). How can urban green spaces be planned for climate adaptation in subtropical cities? Ecological Indicators, 82, 152–162. https://doi.org/10.1016/j.ecolind.2017.07.002

Zhang, C., Kazanci, O. B., Levinson, R., Heiselberg, P., Olesen, B. W., Chiesa, G., … Zhang, G. (2021). Resilient cooling strategies – A critical review and qualitative assessment. Energy and Buildings, 251, 111312. https://doi.org/10.1016/j.enbuild.2021.111312

Zimmerman, R., Brenner, R., & Llopis Abella, J. (2019). Green Infrastructure Financing as an Imperative to Achieve Green Goals. Climate, 7(3), 39. https://doi.org/10.3390/cli7030039