Heat Mitigation & Adaptation Guidebook

Resources for Charlottesville, VA

CHARLOTTESVILLE
Acting on Climate Together

Executive Summary

As climate change transforms cities and regions across the United States, rising temperatures threaten urban infrastructure, human health, and liveability. Urban heat poses a growing challenge to the City of Charlottesville, though local efforts have traditionally prioritized other environmental hazards such as heavy precipitation and increased flooding. This is beginning to change. With completion of a Heat Watch mapping campaign in 2021, a Climate Risk & Vulnerability Assessment in 2022, and the planned development of a Climate Adaptation Plan in 2023, the City of Charlottesville is attempting to identify, visualize, and address the threats posed by extreme heat. Of particular interest are the extent to which specific communities and areas are impacted by rising temperatures, and what the City and the Charlottesville community can do to support heat resilience locally.

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 may exist at the household level and/or 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., flooding and air pollution). This guidebook presents solutions which are supported by existing literature, and which are suitable for the humid climate of Charlottesville.

Of the multiple solutions to mitigate heat, the literature overwhelmingly points to tree planting and preservation as the most effective 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 Charlottesville has already dedicated significant resources to the exploration of a greening and tree-based environmental strategy in the *City GreenPrint 1.0* green infrastructure guide. However, trees are not appropriate in all situations.

The purpose of this heat-specific guidebook is to offer alternative cooling strategies, and trees alone will not be centered in subsequent sections. 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 Charlottesville, and reviews the known benefits and challenges associated with a tree-based approach to heat mitigation.

Community 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, 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 Charlottesville 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	Grass or other vegetation; Community gardens; Urban agriculture
	Blue-green infrastructure	Bioswales; Permeable pavements
	Pedestrian and active transportation infrastructure	"Complete Streets" and/or "Cool Streets;" Bike lanes; Shade structures; Pedestrian safety improvements
	Energy efficiency updates	Weatherization; Retrofits (applies to all building types)
	Alternative energy systems	Solar; Geothermal; District cooling; Microgrids
	Legislation and policy changes	Development; Funding; Heat response; Health
	Financial and technical assistance	Subsidies and rebates; Tree planting and maintenance help
	Community education	Value of trees; Heat safety and risk
	Job training and volunteer corps	Activating community stewards; Building wealth in underserved communities
	Emergency response and giveaways	N/A
Household Scale	Small-scale applications of Community Scale strategies	Residential tree planting; Green, 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	N/A
	Insulation and venting	N/A
	Shades, overhangs and window films	N/A
	Self cooling and rest	Individual, health-based strategies

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Household Scale Strategies for Heat Mitigation & Adaptation

Using this Guidebook

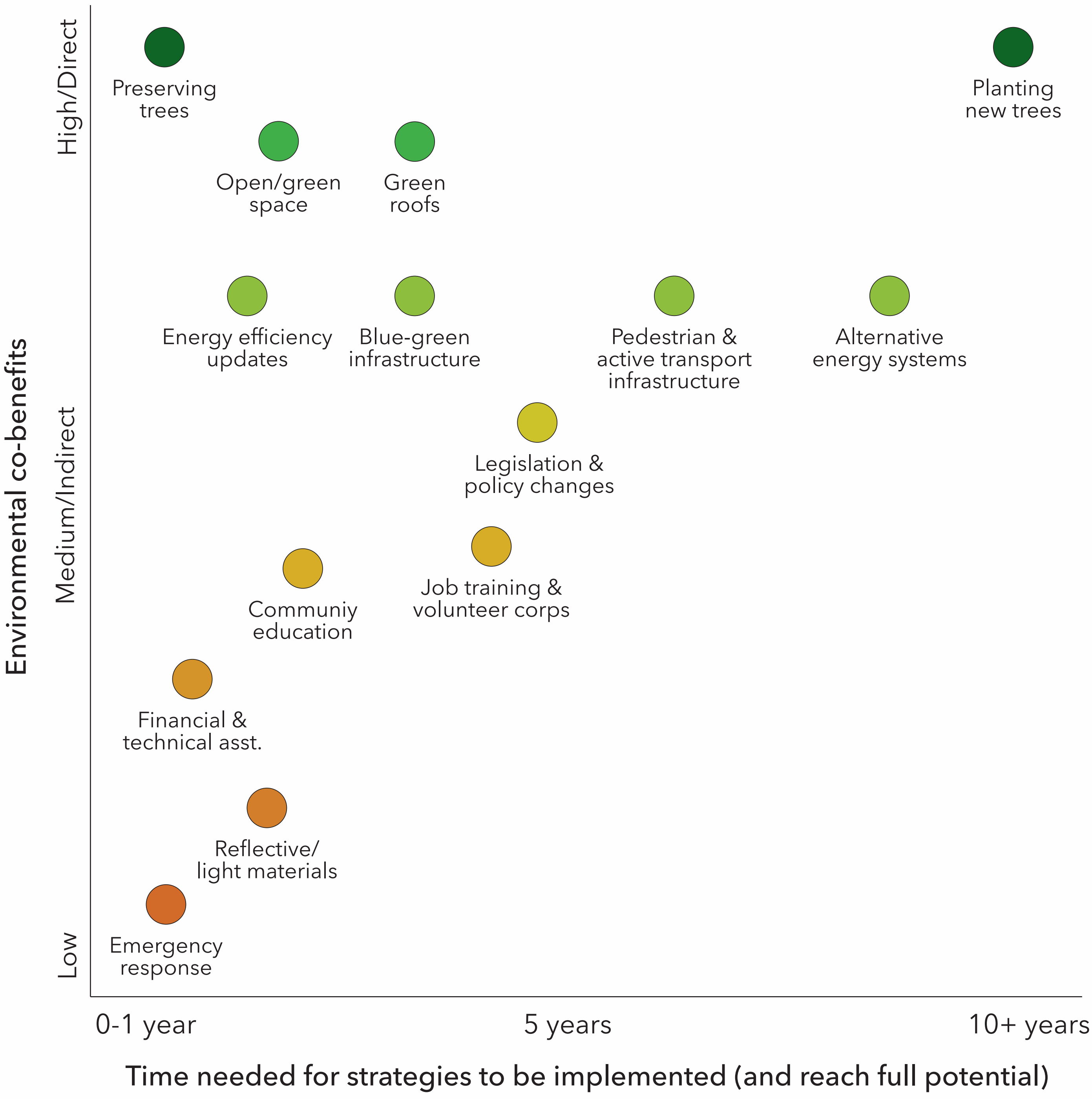
This guidebook is a resource for municipal staff, partners, and community members in Charlottesville which can help initiate and inform early conversations about heat mitigation and adaptation in the city. There are many options for addressing urban heat, and countless nuances, best practices, costs, and benefits associated with each. The ideas presented here reflect a suite of concepts and interventions that have been selected for Charlottesville 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 realm 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 palatability. Municipal leaders, managers, planners and their professional partners are encouraged to use this information as a jumping off 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 Charlottesville, heat mitigation integration and resources, and considerations 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 community scale. These 'Community 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, 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 are relatively more expensive and time consuming than those offered as 'Household Scale' strategies, and make an impact at a larger scale.

The chart below offers a characterization of the Community 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 pertinent 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. Other measures which do not have direct environmental benefits but would likely contribute indirectly to those listed are identified as having medium/indirect co-benefits. 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 not be taken as an absolute reflection of reality, but rather as a conceptual aid.

Overview of Community Scale Heat Mitigation & Adaptation Strategies



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 Community 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

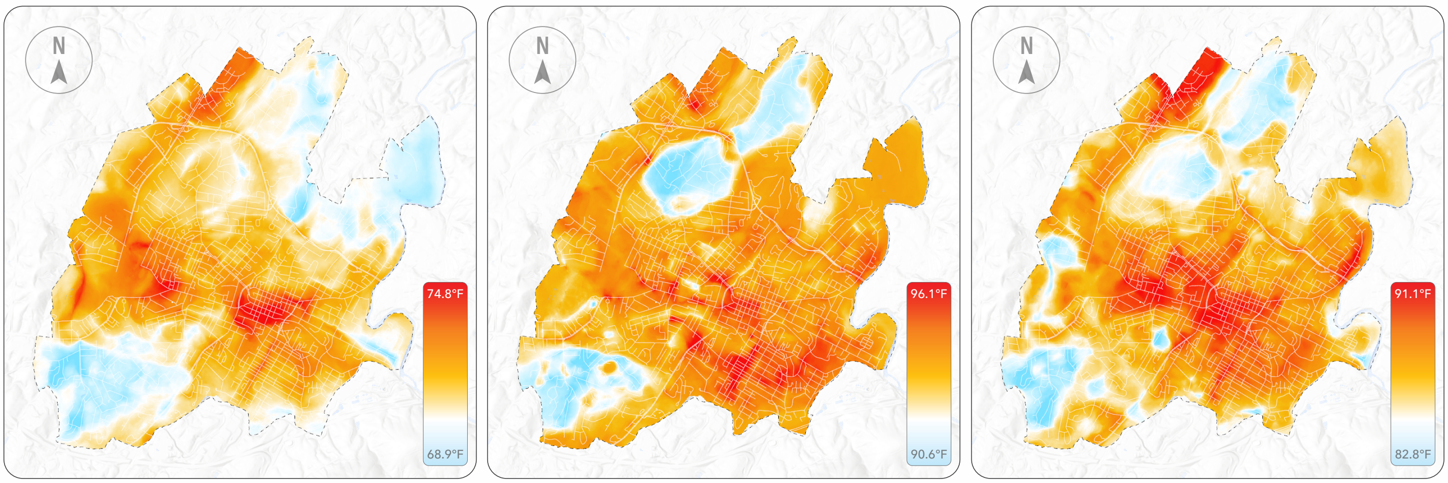
1.1 Climate and environmental challenges in Charlottesville

Charlottesville, VA is located within the humid subtropical climate zone that spans most of the southeastern United States. This zone, also known as 'Cfa' in the Koeppen-Geiger classification system (Koeppen-Geiger, 2022), 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, 2022).

Weather patterns in Charlottesville are consistent with a typical humid subtropical climate zone (Climate-Data, 2022). However, as in many cities worldwide, annual weather in Charlottesville has been undergoing a shift. In 2021, maximum daily temperatures exceeded the 30-year average maximum value 18 times in June, 22 times in July, and 21 times in August. During these three months, high temperatures at or above 90°F were recorded on 42 separate days, and the temperature reached a maximum of 98°F two times in August (Weather Underground, 2022). A report from the Community Climate Collaborative (C3, 2020) suggests that temperatures in Charlottesville will continue to rise, with 20 days per year over 105°F by midcentury. Like all cities, Charlottesville is prone to the 'urban heat island effect.' This means that impervious surfaces absorb heat from the sun while concentrated human activities, like driving, add heat to the air, leading to higher temperatures in heavily developed areas. Flooding, too, will increase as extreme precipitation events increase in frequency and intensity, continuing a trend which has already begun in the region (C3, 2020). More information on the anticipated effects of climate change in Charlottesville and about Charlottesville's urban heat can be found on the City's website: charlottesville.gov/climateplan and charlottesville.gov/1469/Urban-Heat.

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, 2022a; 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, 2022b; 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.

Studies by the City and CAPA Strategies have shown that in Charlottesville, as in many US cities, heat is not evenly distributed. Lower-income areas of the city are more built out, 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).



Morning, afternoon, and evening area-wide models for distribution of near surface temperature (°F) in Charlottesville. Source: CAPA 2021 Heat Watch

Flooding has been an ongoing challenge in the Charlottesville area, and its effects are highly visible, physically damaging, and costly (C3, 2020). Accordingly, effort at the municipal level has been directed toward flood mitigation and adaptation. In contrast, 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 major heat events – can have widespread public health consequences (National Weather Service, 2022).

1.2 Integrative heat mitigation and adaptation solutions

The City of Charlottesville 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 air pollution (see chapter *3.2 Pedestrian and active transportation infrastructure*); to control stormwater flow, storage, and flooding (see chapter *3.3 Green and blue infrastructure*); and to alleviate the cost burden associated with commercial and residential energy use (see chapter *3.4 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 such as flood control 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 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 Charlottesville. Such interventions fit into the bigger picture of climate change, 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:

City of Charlottesville Resources

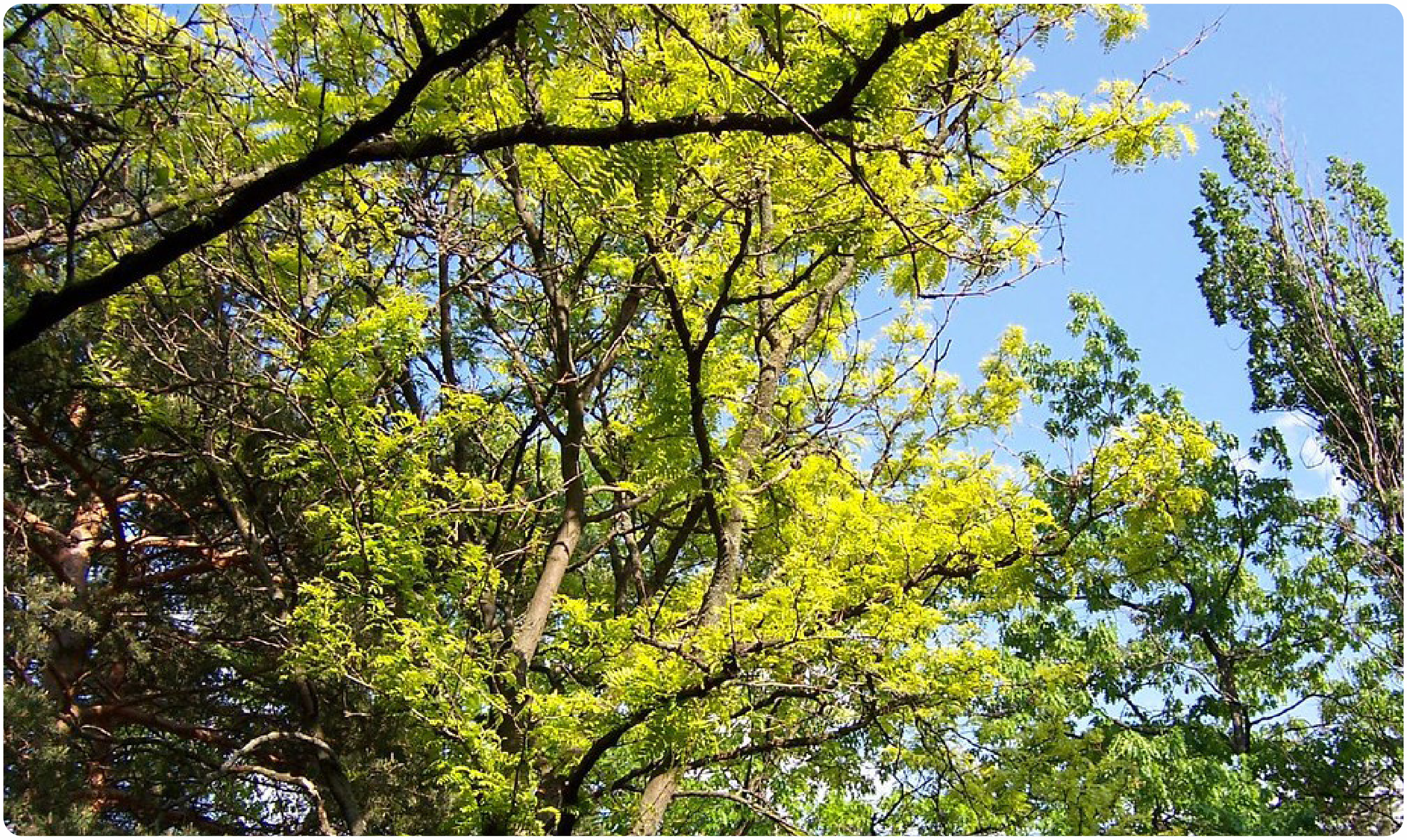
- Charlottesville Climate Action Plan (GHG Emissions Reductions)
- Climate Program webpage
- Urban Heat Island webpage
- Charlottesville Climate Risk and Vulnerability Assessment
- City of Charlottesville GreenPrint 1.0
- Urban Forestry webpage
- Tree Inventory and Interactive Dashboard
- Urban Canopy Tree Reports
- Charlottesville Master Tree Planting List

Charlottesville Community Resources

- Charlottesville-Albemarle-UVA 'Climate Action Together: A Roundtable Discussion About Local Implications of Climate Change on Our Community's Health, Safety, and Ecology' (video recording,YouTube)
- Community Climate Collaborative (C3) 'Local Effects of Climate Change' Report (Charlottesville area)
- Resilient Virginia

Trees are a go-to solution for urban cooling, with good reason. They provide a host of benefits for people, animals, and the environment at large. For a deeper look into the state of trees and other green infrastructure in Charlottesville, please refer to the 'City GreenPrint 1.0: Charlottesville's Green Infrastructure Guide.' Readers can also find the City of Charlottesville's master tree list and planting tips here.

2: Trees



2.1 Benefits of trees

When cities and communities are planning for heat mitigation and adaptation, trees typically come to mind as 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 (Qui 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 Charlottesville in 2021 showed that some parts of the city – those least vegetated and suffering the most severe impacts of the urban heat island effect – were over 8°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, 2022). 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, 2022).

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. Concerns which emerged as the City of Charlottesville developed its recent Climate Action Plan included "costs for maintenance, damage from downed limbs, and roots impacting utility lines." Residents may also be put off by the upfront costs associated with tree planting and maintenance, or may not appreciate the tree's broader value to themselves (e.g., future energy savings and increased property values) and their community. While these limitations 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 Charlottesville, a 7a 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. Climate mitigation efforts often depend on placing homes and businesses in closer proximity to each other within existing urban areas.
- The presence of power lines and utility lines – including those underground such as water, sewer, stormwater, and gas – creates a conflict and limits the potential placement options for new trees.
- Trees cool the atmosphere via evapotranspiration but do not alleviate humidity. In Charlottesville, 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.
- 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, 2022). 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, some native tree species may become less suitable over time. It is recommended that the City of Charlottesville 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 latest master tree list with preferred species can be found 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).
- Engage with local communities, obtain public buy-in, and consider anti-displacement measures from the start to 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, plan for at least three to five years of monitoring and maintenance, including a regular watering schedule. This plan should clearly designate the responsible party and funding sources.
- Consider tree-based heat mitigation strategies which 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, 2022).

3: Built environment and infrastructure

3.1 Building regulations and zoning

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 Virginia is subject to the Dillon Rule, which prevents deviation from statewide building standards, Charlottesville is limited in its ability to impose new codes. Examples from nearby localities offer some guidance on effective ways to work around this rule.

- 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.
- 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 targets pertinent to heat mitigation include:

Cool roofs, building materials, 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.

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.

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).

3.2 Pedestrian and active 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 Charlottesville is a way to simultaneously mitigate heat, reduce emissions and air pollutants, and promote community health via active transportation (Glazener & Khreis, 2019). Options include adding new bike lanes to large roads, and/or designating select small roads as bike-only thoroughfares closed to non-resident traffic; adding or improving pedestrian pathways (e.g., improving the condition of sidewalks and street lighting, placing safety barriers between pedestrians and automobiles); and increasing the reach of bus routes and frequency of trips. “Complete Streets” design policies guide the integration of pedestrian- and alternative transportation-friendly infrastructure into urban development (Jordan & Ivey, 2021). Charlottesville passed its own Complete Streets Resolution in 2014, and adopted the related “Streets that Work” design guidelines in 2016 (City of Charlottesville, 2016).

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 shelters at bus stops, placing public water fountains along popular commuter routes, and shading walking or biking paths to protect commuters from sun and heat exposure (Lanza & Durand, 2021). Tips for effective shading (United Nations United Nations Environment Programme, 2021):

- Prioritize busy commuter routes for shading upgrades, whether planting trees or installing new shade structures (Jay et al., 2021).
- Place new bike or walking paths close to existing tall buildings or trees, which provide shade.
- Utilize permeable and/or light pavements along pedestrian and bike paths to cool the path surface and assist with stormwater capture.
- 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.

Consideration:

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 is also high and may decrease the cooling potential of shade structures for commuters.

Case Study:

MILWAUKEE, WISCONSIN COMPLETE STREETS INITIATIVE

When the state of Wisconsin repealed its Complete Streets policy in 2015, Milwaukie Public Works decided to implement a localized version which reflected its urban context and culture. The new policy was devised in a collaborative approach between City staff, community advocates and elected officials, and was passed in 2018. That year, it was graded as the third best Complete Streets policy in the US (Smart Growth America, 2019). In 2021, the number of major transportation projects incorporating Complete Streets in Milwaukee was 50%, up from 30% in 2020, and 9% in 2019. During the past three years, the City has installed new protected bike lanes, bicycle boulevards, street trees, and bioswales under this policy. Complete Streets and related neighborhood improvement projects are regularly designed with community input and target a combination of environmental and social challenges (City of Milwaukee, 2022).

3.3 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.

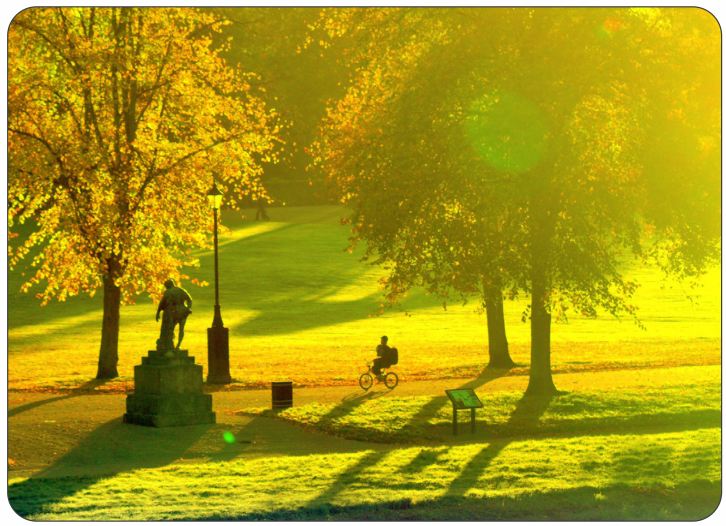
(B)GI is recommended as a heat mitigation and adaptation strategy, though there are specific details to be aware of when choosing the right approach for Charlottesville's humid subtropical climate.

Trees

- 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. As noted in the City GreenPrint 1.0 guide, the City of Charlottesville has already established and met a canopy target of 40%. However, as also noted, that coverage is not evenly distributed across the city. Additionally, a new report found that canopy has decreased in recent years (Charlottesville Parks & Rec, 2022). 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 the loss of existing canopy (Ouyang et al., 2021).
- 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.

Green roofs

- 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, 2022). Green roofs and walls can effectively reduce indoor temperatures, and offer insulation which reduces energy burdens for cooling. 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).



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 and other vegetation are distributed throughout (Yu et al., 2017).
- 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 grass-only spaces.

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 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, green space, and other types of vegetation 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).

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.

Also like trees, all forms of (B)GI have the potential to trigger an increase in property values, green gentrification, and displacement of residents in formerly underserved areas. It is recommended that the City consider anti-displacement measures and ways to deal with unintended consequences before implementing major (B)GI projects (Curran & Hamilton, 2012).

3.4 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 truly 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 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 Charlottesville may identify). 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 solar panels atop structures that can support them. The typical weather patterns of Charlottesville 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, microgrids may provide an answer.

- Microgrids distributed throughout the city can serve as backup when the primary grid fails, and may be especially useful when placed in high-risk neighborhoods (i.e., where sensitive populations are concentrated or where heat exposure is highest). These localized grids potentially support the use of alternative energy (solar, geothermal) which can be collected at homes or critical structures (e.g., hospitals), 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. The implementation of microgrids, including subsidies for low-income residents to access alternative energy infrastructure (e.g., solar panels), would require upfront investment by the City or other funding partner.
- 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 Charlottesville include (Think Microgrid, 2022):
  - **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
  - **Grid-connected:** tied into the central power grid but can be separated as needed

Case Study:

GREATER BOSTON, MASSACHUSETTS MICROGRIDS

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 (Gastelum, 2022; Gellerman & Greene, 2021).

4: 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, cleaning debris out of bioswales, or resurfacing reflective roofs. 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, Charlottesville adopted a Stormwater Utility Fee in 2013. 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 State Water Control Board, the Department of Environmental Quality (Stormwater Local Assistance Fund), and the Department of Conservation and Recreation (Community Flood Preparedness Fund)
    - 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

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 Development standards

Policies and legislation which direct future citywide development can enable heat mitigation solutions identified elsewhere in this guidebook, such as green infrastructure, alternative energy strategies, and pedestrian-friendly environments. Some common development standards include:

- Allow for dense development within city limits and implement density goals as described in Charlottesville's 2021 Comprehensive Plan. This includes relaxing limitations on the placement of multi-family housing, and allowing missing middle ("soft density") development. Dense development prevents sprawl and protects forested areas surrounding the city which capture carbon and stormwater, improve local air quality, and cool the region.
- Balance densification and removal of trees with new tree planting and the preservation of mature trees and forest stands. No amount of cooling infrastructure within the urban center will match the ecological and social benefits provided by mature forests, and those assets should be protected even as new heat mitigation measures are taken.

- Coordinate new developments to enable district cooling or energy sharing and configure them to maximize shade and airflow.
- Configure new developments to maximize continuous open space, leave room for ample tree planting (e.g., widen medians and sidewalks), and prioritize public and active transportation (e.g., design thoroughfares which are not open to personal vehicle traffic).
- Plan to site residential developments, public health facilities, and facilities serving sensitive populations away from environmental hazards such as industrial sites and highways which generate heat and air pollution.
- Pursue integrative zoning and design solutions which address multiple environmental hazards simultaneously, and utilize a mix of the specific solutions offered throughout this guidebook. For example, consider the "Cool Streets" approach, first developed in Australia and gaining traction in the US (Cool Streets, 2019). Notably, in keeping with the original concept, Cool Streets projects should be designed in collaboration with local communities to increase buy-in, satisfaction, and feelings of ownership (see chapter *5.4 Engagement, integration, and buy-in*).

Case Study:

SILVER SPRING, MARYLAND COOL STREETS GUIDELINES

In 2022, Silver Spring adopted Cool Streets guidelines for its downtown area. Following these guidelines, planners may coordinate the use of street trees, light and permeable pavements, shade structures, wind ventilation, and evaporative cooling for maximum effect. These integrated interventions have significant potential to reduce the urban heat island effect, improve pedestrian safety and comfort, and provide stormwater control. They can also support goals such as reducing energy use in surrounding buildings, enabling active transportation, and reducing carbon in the atmosphere.

Considerations:
It is recommended that any development standards pertinent to heat mitigation be accompanied by appropriate housing policies, including rent stabilization. This is a way to ensure that cool developments and infrastructure do not lead to unintended consequences such as increasing property values, unstable rental prices, and displacement of longtime residents, particularly in underserved communities (Pallathadka et al., 2022).

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, 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, 2022).

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, and the development of effective heatwave alert systems (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 Virginia Department of Health Blue Ridge Health District 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, 2022). 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 ease the burden. Providing support around proper tree care and maintenance may also ease residents' concerns and improve outcomes. Popular examples include:

- Public subsidies or rebates for weatherization, energy upgrades, or installation of GI which offset prohibitive costs (Cousins & Hill, 2021).
- Free tree giveaways by the City or non-profit partners.
- Free training for residents who wish to plant and steward trees or GI on their properties or in their communities. Such training may come from a certified arborist, master gardener, GI designer, or other appropriate advisor contracted by the City.

Case Study:

TREE NEW MEXICO

Tree New Mexico (TNM) is a statewide non-profit group based in Albuquerque, which focuses solely on tree planting and tree-based education. The organization uses a mix of community planting events, free tree giveaways, and educating residents about the value of trees to get plants in the ground. Technical education is also provided to ensure long-term sustainability of newly planted trees. To this end, TNM offers training on topics such as tree and site selection, tree planting and care, proper tree pruning, trees and beneficial insects, and identifying and addressing tree problems. Education is supported by state and local experts in urban forestry and arborists, and TNM has been growing the state's urban forest for over 30 years (Tree New Mexico, 2022).

5.2 Education campaigns

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 Charlottesville, 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.

5.3 Job training and volunteer corps

Getting Charlottesville 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).

Case Study:

GROUNDWORK OHIO RIVER VALLEY GREEN CORPS (CINCINNATI)

Groundwork is a national non-profit organization dedicated to sustainably managing and improving the natural environment through empowering, socially just, community based partnerships. The Ohio River Valley (ORV) chapter, based in Cincinnati, OH, works closely with young adults through its Green Corps program. This workforce development program imparts valuable training and experience in a range of green jobs and offers paid work opportunities. Jobs for which corps participants are trained include removing invasive species, planting orchards, propagating native plants, and installing green infrastructure assets (Groundwork ORV, 2022).

5.4 Engagement, integration, and buy-in

The preceding suggestions for social support are all in service to a common goal: increasing public engagement, integration, and buy-in with regard to heat mitigation and adaptation efforts. For such 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.

5.5 Emergency response and resource giveaways

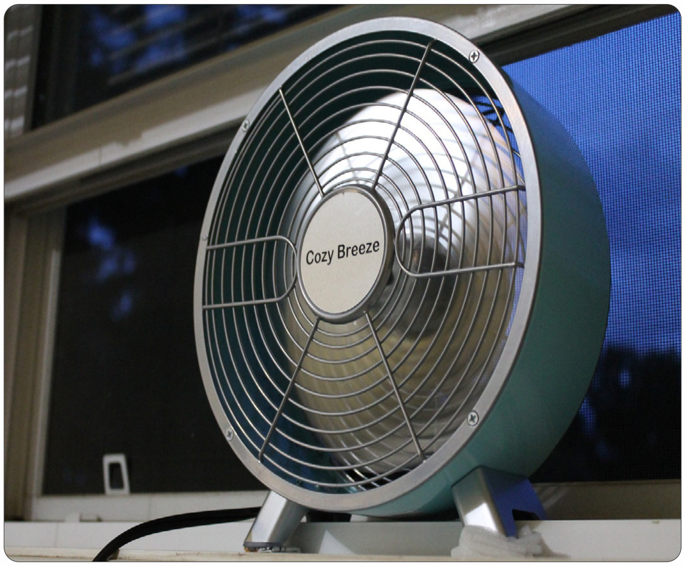
Simultaneously working toward heat adaptation and mitigation is critical, as highlighted in the preceding sections. However, even in the most prepared cities, extreme heat events and emergencies do occur. The City government can be ready with a robust heat emergency response protocol which directs resources and attention to high-risk areas and communities. This may include opening public cooling shelters and offering residents help with rides (e.g., subsidizing trips on city buses or offering pickup services to vulnerable or mobility-challenged groups); giving away bottled water, fans, misters, or air conditioning units; activating wellness checks; sending citywide alerts; or putting local hospitals on notice, as heat related illness is sometimes mistaken for other conditions in emergency room settings. Emergency plans which coordinate City resources with the networks of community-based groups may help responders access high-risk populations.

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 Community 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, 2022).
- 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).

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

For residents without air conditioning: Without an air conditioner, 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 conditioner 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, 2022).

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 utilities and the State for insulation and air sealing. Local non-profits, such as The Local Energy Alliance Program (LEAP), are the service providers for these funds and a good first-step resource (visit https://leap-va.org/ for more information). 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, 2022b). It is important to limit physical activity and exertion in the heat (indoor and outdoor) when possible, and rest when you feel overheated. 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

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