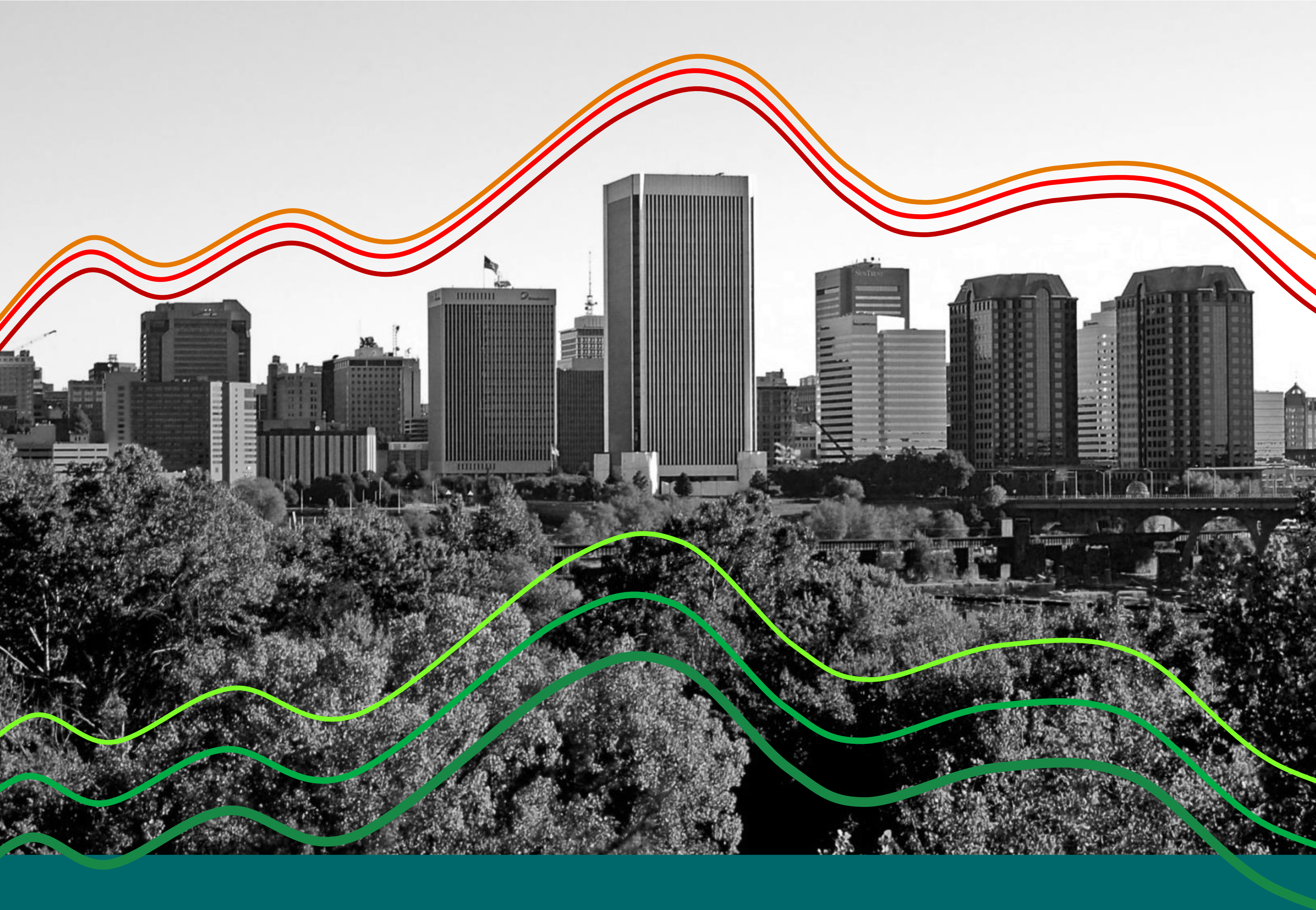
Made in the Shade

Cooling the Urban Heat Island Effect in Richmond, Virginia

Ben Stolz
APP Report
2020



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Client

This report was prepared for the Mayor's Office in Richmond, Virginia.

Disclaimer

The author conducted this study as part of the program of professional education at the Frank Batten School of Leadership and Public Policy, University of Virginia. This paper is submitted in partial fulfillment of the course requirements for the Master of Public Policy degree. The judgments and conclusions are solely those of the author, and are not necessarily endorsed by the Batten School, by the University of Virginia, or by any other agency.

Honor Pledge

On my honor as a student, I have neither given nor received unauthorized aid on this assignment.

Ben Stolz
May 12, 2020

UNIVERSITY of VIRGINIA
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Glossary and Acronyms

Adaptation – initiatives that assist communities with becoming more resilient in the face of climate change's effects

Albedo – the measure of how much solar energy is reflected by material, and is an important factor in estimating the near-surface temperature of a pavement structure

Evapotranspiration – the process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces, and by transpiration from plants

Extreme heat – a long period of high heat and humidity with temperatures above 90 degrees

Green architecture – an approach to building that minimizes the negative effects construction can have on the environment

Greenhouse Gas (GHG) Emissions – any gas that has the property of absorbing net heat energy emitted from the Earth and reradiating it back to the Earth's surface

Impervious/impermeable surface – mainly artificial structures, such as pavements, that are covered by water-resistant materials such as asphalt, concrete, brick, or stone

Land use type – involves the management and modification of the natural environment or wilderness into a built environment like settlements and semi-natural habitats

Locality – a distinct population cluster in which inhabitants live in neighboring sets of living quarters which has a name or locally recognized status

Mitigation – initiatives that aim to directly lessen climate change's effects

Short-wave energy – radiant energy with wavelengths in the visible (VIS), near-ultraviolet (UV), and near-infrared (NIR) spectra

Smog formation – the process by which intense air pollution is formed

Thermal energy – also known as heat energy, is the energy that comes from the temperature of a heated substance

Urban Heat Island Effect (UHIE)/ Urban Heat Island (UHI) - an urban or metropolitan area that is significantly warmer than its surrounding rural areas due to human activities

Executive Summary

Extreme heat is the number one weather-related cause of death in the United States (Kenward et al., 2014). In July of 2019, the United States faced the hottest month ever recorded (Fountain, 2020). Some neighborhoods have been hotter than others.

In Richmond, Virginia, **it is as much as 16 degrees hotter in poorer, more industrialized, neighborhoods of color than wealthier, greener, whiter areas, at the same time on the same days.** This phenomenon, known as the urban heat island effect (UHIE), occurs because unshaded roads and buildings capture heat and spread it to its surroundings increasing the temperature. If nothing is done to address this issue, by 2050, Richmond as a whole could have 40 to 50 more days above 95 degrees a year (Moyler, 2019). More so, Richmond will continue to have disproportionate rates of heat-related illnesses and energy usage, along with damaging effects to the economy and environment.

Journalist Sam Bloch recently noted, shade has become “a civic resource, an index of inequality, and a requirement for public health. Shade should be a mandate for urban planners and designers” (Bloch, 2019). This report responds to this mandate by summarizing Richmond’s unique context, exploring cooling best practices from cities across the world, presenting options to address the issue, and proposing a recommendation and implementation plan to solve the problem in the long-term.

This report considers three options to cool the UHIE in Richmond: 1) Revise Richmond’s tree ordinance, 2) Utilize the master planning process to propose a package of zoning regulations, and 3) Create an urban forestry management plan. These options are evaluated based on effectiveness, equity, costs, political feasibility, and administrative feasibility.

The recommendation is to **create an urban forestry management plan**. This recommendation has the potential to score high on effectiveness and equity in the long-term, and it is relatively easy to implement, especially given all city departments are currently crafting the city’s master plan to design Richmond’s next 20 years. The implementation plan includes three broad steps: 1) Recruit diverse stakeholders for an urban forestry management plan task force, 2) Create an urban forestry management plan, and 3) Conduct a tree-planting pilot project.

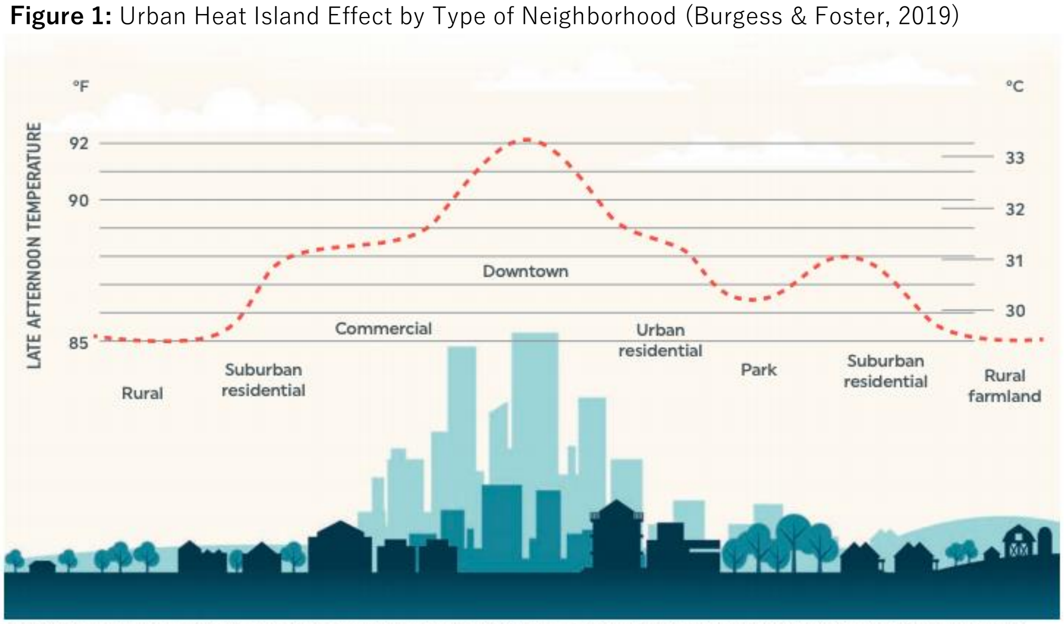
Taking such actions could lay the foundation for a cooler Richmond for all.

Problem Statement

Extreme heat is the number one weather-related cause of death in the United States (Kenward et al., 2014). In July of 2019, the United States faced the hottest month ever recorded (Fountain, 2020). Some neighborhoods have been hotter than others. In a study of the country's 60 largest cities, cities averaged at least eight more days over 90 degrees each summer compared to the closest rural areas (Kenward et al., 2014). As seen in **Figure 1**, this phenomenon, known as the urban heat island effect (UHIE), occurs because unshaded roads and buildings capture heat and spread it to its surroundings increasing the temperature. Furthermore, low-income neighborhoods and neighborhoods of color are often adversely affected, with temperatures in those neighborhoods being as much as 20 degrees hotter on some days (Meg Anderson & McMinn, n.d.).

This is true of Richmond, Virginia and its rural neighbors, but is displayed more strikingly between neighborhoods within the city. **It is as much as 16 degrees hotter in poorer, more industrialized, neighborhoods of color (the Diamond, Highland Terrace, Newtown West, Old Town Manchester, and Scott's Addition) than wealthier, greener, whiter areas, at the same time on the same days.** As a result, if nothing is done, by 2050, Richmond as a whole could have 40 to 50 more days above 95 degrees a year (Moyler, 2019). More so, Richmond will continue to have disproportionate rates of heat-related illnesses and energy usage, along with damaging effects to the economy and environment.

Figure 1: Urban Heat Island Effect by Type of Neighborhood (Burgess & Foster, 2019)



The average air temperature of a city with 1 million or more people can be 1.8° to 5.4°F warmer on average and as much as 22°F hotter at night than surrounding areas because of the urban heat island effect.[17] (Heat Island Group, Lawrence Berkeley National Laboratory, 2019)

Background

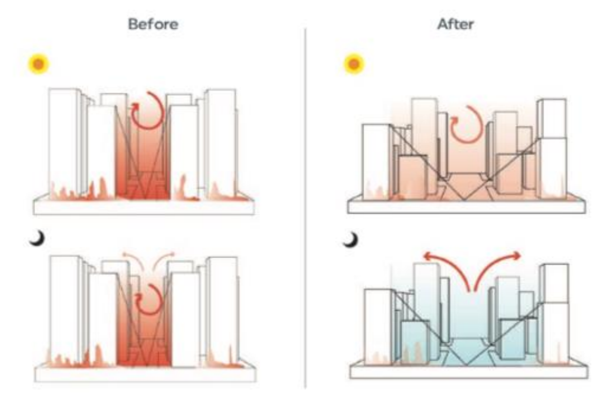
OVERVIEW

This section reviews the causes and consequences of the UHIE broadly, takes a closer look at the phenomenon within Richmond, and summarizes what is currently being done to address it.

Causes of the UHIE

The UHIE has a range of causes. First, land use change is an issue. Throughout the United States, areas are becoming hotter because green spaces are mostly being replaced by residential and commercial buildings. Green spaces have lower temperatures because trees decrease short-wave radiation and vegetation emits less energy as a result of evapotranspiration. Evapotranspiration is the combination between evaporation and transpiration. On the other hand, impervious surfaces, such as concrete, brick, or stone, absorb short-wave energy and re-emit long-wave thermal energy, which increases temperature. These materials have the ability to store a lot of heat and make their surroundings much hotter (J.-P. Kim & Guldmann, 2014).

Figure 2: Building Height and UHIE (Burgess & Foster, 2019)



The diagram shows how taller buildings prevent streets from cooling at night and how building height could be modified to allow heat dissipation. (NYIT Urban Design Climate Lab 2017)

Secondly, UHIs are caused by urban design. The pattern of streets and buildings, building types, and buildings' heights play a significant role in a city's temperature. In a study of 50 cities around the world, there was a strong correlation found between urban design and evening temperatures (Sobstyl et al., 2018). As seen in **Figure 2**, taller buildings, especially in dense areas, can lead to increased heat in an area by trapping heat and dispersing it throughout the area. Moreover, studies have found correlations between height-to-width ratios of street canyons and temperature within a city (Takkanon, 2016).

Lastly, waste heat emissions cause the UHIE. Primarily, this is a result of energy use indoors from air conditioners and energy use outdoors from transportation. Additionally, air pollution contributes to the UHIE. Air pollution and suppressed wind, combined with urban heat islands (UHIs) create conditions for smog formation, which serves as a heat-trapping barrier, multiplying the effect of UHIs. In fact, UHIs account for 20 percent of smog formation (Burgess & Foster, 2019).

Consequences of the UHIE

UHIs impact people's health, especially vulnerable populations such as children, the elderly, people with pre-existing conditions, and people living in under-resourced circumstances. Emergency room visits tend to increase because of symptoms such as heat exhaustion and cramps. In dire cases, these symptoms lead to death.

There are also wide-reaching economic impacts. Due to the UHIE, GDP could decrease by as much as one-third by 2100 due to a decrease in labor productivity and agricultural output (Burgess & Foster, 2019). Regarding labor productivity, UHIs could affect indoor and outdoor laborers. Productivity decreases outdoors because of precautions that need to be made for workers' health. Satisfaction decreases for workers indoors with poor insulation. From Moody's Investor Service to S&P Global, credit-raters have anticipated growing negative credit factors for those who do not have climate mitigation and adaptation plans. Moreover, UHIs can impact consumers' purchasing habits. For example, the 2017 California wildfires, which UHIs contributed to, decreased retail and restaurant foot traffic by 40 percent (Burgess & Foster, 2019).

Additionally, there are costs to infrastructure. Increased temperatures take a toll on roads and public transportation eventually leading to roads and rail tracks buckling. This would likely lead to people using public transportation less. Furthermore, as air conditioner demand and use increases, so does the harm to the environment. The greenhouse gas emissions from cooling machines exacerbates rising temperatures.

Lastly, UHIs affect species migrations due to habitat changes, and there are significant water management effects. For instance, pavements that are 100 degrees can increase rainwater temperature from 70 to 90 degrees, which leads to increased temperatures of natural waterways. This could lead to negative effects for aquatic species and makes it harder to manage stormwater and landscapes.

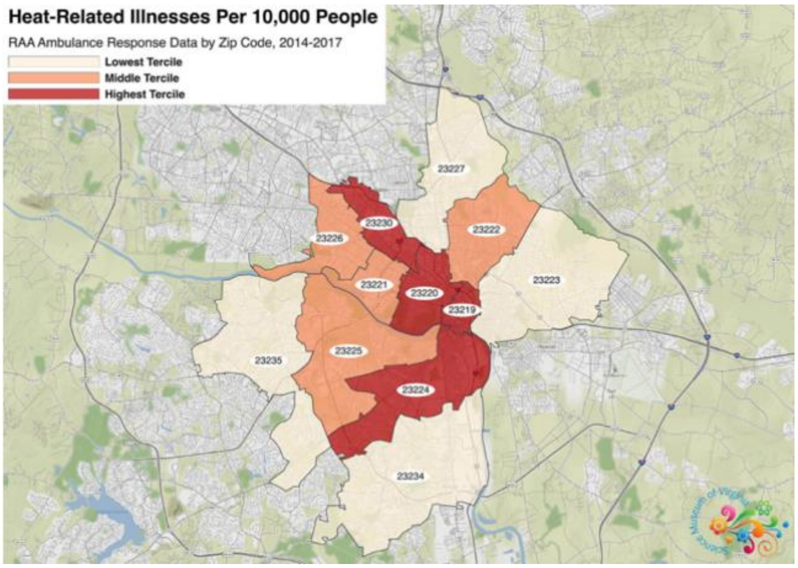
The UHIE in Richmond

On July 13, 2017, a day with a record-breaking average temperature in Richmond's history, a group of scholars, students, and community organizations came together to tackle the issue of the UHIE in their city. Hand-made devices with electronic temperature sensors and GPS units were constructed to track temperature and location every second the device was used. While driving in cars or riding bikes, 15 volunteers collected data for an hour at 6 am, 3 pm, and 7 pm across Richmond. Taking temperatures at these different time intervals allowed the team to collect data on the differences in heat at different times of the day in different areas. Their work amounted to over 100,000 temperature readings in total.

First, the study confirmed research done in other areas. Forested and vegetated areas are cooler than more urbanized areas, high-density areas with little vegetation and major arterial roadways amplify heat, and morning high temperatures are always lower than afternoon and evening low temperatures.

The most groundbreaking finding was it was as much as 16 degrees hotter in some areas of the city than other areas at the same time on the same day. Specifically, temperatures reached 87 degrees outside of the middle of the city, and 103 degrees in the extended band of dense development in the center of the city (Poon, 2019).

The cooler places in the city (the Dogwood Dell Loop trail and Stratford Hills) have a lot of shade from trees and vegetation. The hottest neighborhoods are in post-industrial areas. They are the Diamond, Highland Terrace, Newtown West, Old Town Manchester, and Scott's Addition (*Insights Report: Background information in preparation for updating Richmond's Master Plan*, 2018). As shown in **Figures 3** and **4**, these neighborhoods are in the following zip codes: 23230, 23220, 23219, and 23224.[1] They have much fewer coverage from trees and contain more impervious surfaces, such as sidewalks, parking lots, and rooftops.



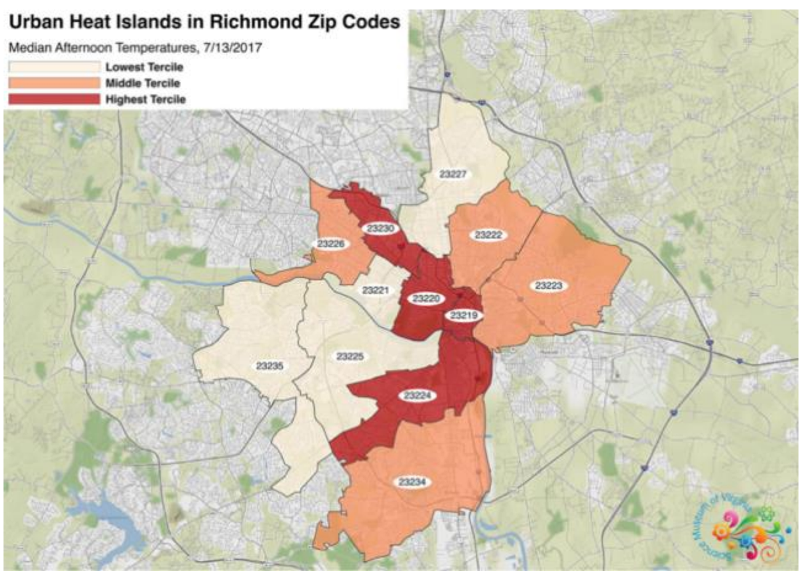
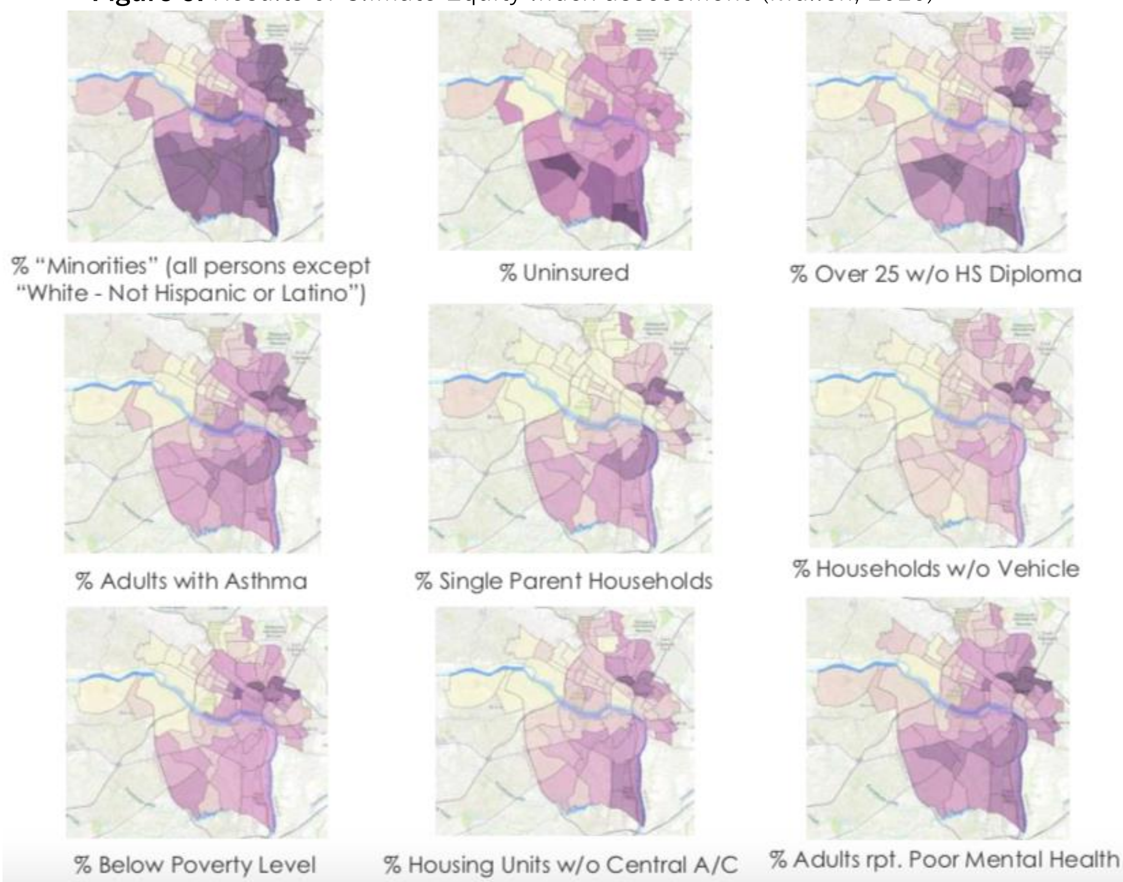


Figure 3: Heat-Related Illnesses in Richmond, VA (Mebane, 2018)
Figure 4: Afternoon Temperatures in Richmond, VA (Mebane, 2018)

[1] See Appendix A Figure 1 for further details.

This finding contained two significant correlations. Firstly, as seen in **Figure 3**, the hottest places are directly correlated with places where there has been the highest rate of emergency visits on the hottest days of the summer. Secondly, the cooler places are among the wealthiest, while the hottest are among the most impoverished in the city. In particular, as seen in **Figure 5**, one can map the hottest places in the city atop the areas that contain the highest percentage of minorities, along with disadvantaged characteristics. Further, one can map these hot spots onto areas that have been most affected by government-led, race-based housing, dating back to the 1930s.

Figure 5: Results of Climate Equity Index assessment (Mullen, 2020)



Redlining in Richmond

In 1933, in the midst of the Great Depression, Congress created a new agency called the Home Owner's Loan Corporation (HOLC) to curtail the urban foreclosure crisis. Within three years, the HOLC refinanced over one million homes, providing lower interest rates and longer repayment periods (Nelson, n.d.). By 1935, the organization that oversaw HOLC, the Federal Home Loan Bank Board, tasked HOLC with surveying 200 American cities as part of the City Survey Program. This was a way to identify trends in housing values across the United States.

Working with local real estate agents, the HOLC created residential security maps. Each neighborhood was graded on an A-D scale, rating neighborhoods by risk.[2] Race was a predominate feature of these grades, all but two of Richmond's neighborhoods were rated "D", and were predominately African American. Of the 200 cities surveyed, 44 percent of HOLC's aid went to neighborhoods that were predominately white, while only one percent went to neighborhoods that were predominately African American (Griego, 2019).

This rating system intensified the issue for communities that were already at a disadvantage. As a result, low-income neighborhoods and communities of color experienced decreased property values and stalled building projects. Nearly 100 years later, close to 75 percent of neighborhoods graded "D" are low-to-moderate income and 64 percent are considered minority neighborhoods (Mitchell & Franco, 2018). Moving from "A" to "D", tree canopy cover decreases, impervious pavement increases, and the mean land surface temperature increases (*Groundwork RVA: Climate Safe Neighborhoods*, n.d.).

A recent study confirmed these findings and took it a step further. Through a spatial analysis of 108 urban areas across the United States, Hoffman, Shandas, and Pendleton found that past housing policy could be "directly responsible for disproportionate exposure to current heat events" (Hoffman et al., 2020). In other words, one can draw a direct line from HOLC's grading system to the UHIE in Richmond. More so, Southeastern cities, like Richmond, experience the greatest difference in temperature between their non-redlined counterparts. What this study confirms is that the story of the UHIE in Richmond is not just one that corresponds with the number of impervious surfaces, but flows from the origins of discriminatory policies a century ago.

Richmond's Current Status

The City of Richmond is currently undergoing a couple of large initiatives. First, Richmond is in the midst of creating its most recent master plan, Richmond 300. It is called Richmond 300 because the plan seeks to create goals that will put the city in a positive position by Richmond's 300th anniversary in 2037. Since 1980, at least after five years, each locality in Virginia has been required to create a "comprehensive plan." While it is broad and aspirational in nature, it is legally required to make land use changes, such as changes related to zoning and special use permits. It is mandated by law to hold public hearings during the process, and afterwards, if City Council does not act in accordance with the recommendations, they run the risk of summoning legal and judicial scrutiny for their

[2] See Appendix A, Figures 2 and 3 for HOLC's security map of Richmond, and Environmental Risk Factors by HOLC Neighborhoods in Richmond.

decisions. There are five working groups. The most relevant one for the UHIE is the Environment Working Group. Along with Chief Scientist at the Science Museum of Virginia, Dr. Jeremy Hoffman, and Richmond's Sustainability Coordinator, Brianne Mullen, there are 35 members on the Working Group. They are tasked with creating recommendations related to creating a thriving environment. City staff will write a draft plan by June of 2020 for adoption by the City Planning Commission and City Council. Implementation is scheduled to start as soon as July of 2020.

Running in parallel with Richmond 300 is RVAgreen 2050. This initiative was announced by Mayor Levar Stoney to develop a plan to reduce greenhouse gas emissions by 80 percent by 2050. More broadly, this is a plan to enhance Richmond's energy systems, and promote more sustainable use of energy in the community. One of the main working groups to come out of this effort is the "Green Team." Their main task has been to increase the proportion of people who can walk to a park. They have two subcommittees, one of which is working on identifying places to convert to green spaces, while the other is looking at existing city policies that need to be updated.

Richmond has been a national leader in assessing their UHIE. Following Richmond's 2017 assessment of the UHIE, Dr. Hoffman, Ms. Mullen, and many others, asked, "which people in particular are being affected in the hottest areas?" From this question, the Sustainability Office created the Climate Equity Index. This is a mapping tool that allows users to explore the "vulnerability and resilience of the Richmond community" (*Climate Equity Index*, n.d.). As seen in **Figure 5**, through this assessment, researchers were able to confirm how the hottest areas overlap with other vulnerable characteristics of the communities concerned. Mullen and her team were also able to narrow down the hottest, most vulnerable areas by Census tract. They identified 32 parcels that are the hottest, and plan to do field visits to the top 10 to consider which cooling interventions would work best in those places.[3]

Finally, the city has a clear understanding of their needs as it relates to responses to the UHIE. STRATUM'S sample survey of Richmond's street trees (Girardi, 2009), the Urban Tree Canopy Analysis of Virginia Localities (McKee, 2010), and the most recent tree inventory *(Tree Inventory, City of Richmond, Virginia, Public Works*, n.d.) give a widespread picture of Richmond's urban tree canopy. The Urban Forestry Division has a goal of planting 2,000 trees per year and has an intimate understanding of their maintenance gaps. There are 120,000 tree sites and 40,000 are currently vacant. As of December 31, 2019, there have been 3,175 open tree maintenance requests through RVA 311, by far the most frequent request on the platform. Furthermore, there are significant vacancies in the Department of

[3] See Appendix A, Figure 3 for a screenshot of these neighborhoods.

Public Works. In particular, there is a need for two additional arborists. There is not an urban forestry management plan, and the tree ordinance was last updated in 1992 (Margaret Anderson, personal communication, March 21, 2020). Despite these gaps, Richmond has dedicated public servants, organizations, and community members who are committed to cooling the UHIE, especially for those who are impacted most by it.

Best Practices

OVERVIEW

Cities across the world have responded to the UHIE in a variety of ways, yet there have been three predominant approaches. They are: expanding the presence and use of urban trees and vegetation (“green growth”), installing green and cool roofs (“green roofs”), and/or implementing cool pavements (“green streets”). At the most basic level, they are all tackled through utilizing four policy instruments: research and strategic plans, outreach and education, regulations and ordinances, and building and zoning codes. For the purpose of gaining a better understanding of each approach, this section discusses the basic elements of each mitigation tactic, the general advantages and disadvantages, and provides a snapshot case study in which a local government has attempted the approach. The case studies will vary in location, success, and duration to communicate a more comprehensive overview of what has been attempted, and to provide a more nuanced view of each approach.

Green Growth

Planting trees and vegetation in strategic locations can have a tremendous impact on the UHIE. This occurs through shading and evapotranspiration. Water is absorbed through trees’ and plants’ roots and emitted through the air. This liquid is turned into gas and cools the environment. In combination with shading, studies have found a cooling effect. For instance, tree groves have been found to be as much as nine degrees cooler than open terrain, and suburban areas with mature trees were four to six degrees cooler than suburbs without trees (US EPA, 2014).

Reducing temperatures not only affect the natural environment; they cool the built environment in nearby areas. As a result of increased canopy coverage, one study found reductions as high as 20 to 40 degrees for walls and roofs, and another study found a decrease of temperature by 45 degrees in parked cars (US EPA, 2014).

Advantages and Disadvantages

Aside from the cooling advantages, trees have positive effects on other aspects of life. They drive down energy costs from air conditioners. In a study of London’s tree-planting program from 2014 to 2018, they found they saved nearly $7 billion in air cooling alone (UK Office for National Statistics, 2020). They also decrease heating costs by blocking strong winds in the winter. Environmentally, trees capture carbon dioxide, reduce carbon emissions, and trap pollution. These effects influence health outcomes, such as reducing the health risks for those with respiratory illnesses and lowering perceived stress levels (Ward Thompson et al., 2019).[4] Lastly, trees can aid with decreasing the need for pavement maintenance (Hoverter, 2012).

Disadvantages include threats to budgets and public safety. Planting and maintaining trees can be expensive because of the materials and training necessary to do it correctly (US EPA, 2014). More pruning and tree removal can lead to additional solid waste, which can lead to damaged sidewalks and power lines (*Reducing Urban Heat Islands: Compendium of Strategies, Cool Pavements*, 2012). Furthermore, Dr. Simon Toze from the Commonwealth Scientific and Industrial Research Organization noted that people in cities across the US have felt less safe walking home at night with more tree coverage in neighborhoods (Nogrady, 2017).

Case Study Snapshot: Washington, D.C. Urban Forestry Program

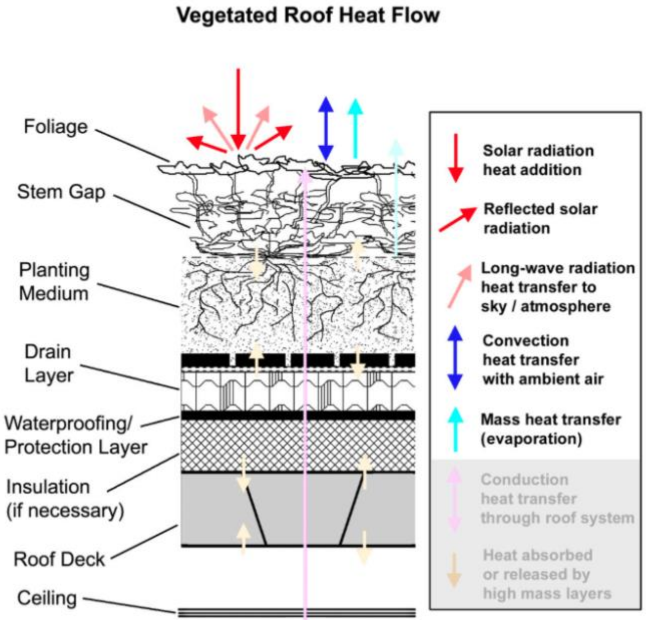
In 2002, the District's Urban Forest Preservation Act was passed, and the urban forest preservation program and Tree Fund were founded. Administered by the District Department of Transportation (DDOT), fees from fines for inadequate maintenance get deposited into the fund to pay for the planting of new trees. In 2012, then-Mayor Vincent Gray, created a sustainability strategic plan, and set a goal for the city to cover 40 percent of the District with healthy tree canopy (Sustainability DC: Sustainable DC Plan, 2011). In four years, the city reached 35 percent tree canopy coverage, reaching almost two million trees across the city in total (Weber, 2016). They are aiming to plant 8,600 trees per year from now until 2032 (esri, n.d.).

DC's success has come through the use of a combination of policy tools. They created the Urban Forestry Administration (UFA) within the District Department of Forestation (DDF). Then, they leveraged new data. They processed Light Detection and Ranging (LIDAR) data from the US Geological Survey to tabulate the quality and number of trees throughout the district (Goldsmith, 2016). This data aided them in enforcing permit laws and more effectively tracking the number of trees planted. Moreover, this data has been utilized as a tool for community outreach and engagement in low-income neighborhoods with low tree canopy. Citizens can see trees planted and maintained in real-time through a website and mobile application. The city and partner organizations also conducted outreach to community members through a canvassing and phone banking program, along with community meetings. They witnessed a significant uptick of tree service requests in those areas following this program (Vibrant Cities Lab, n.d.).

[4] See Appendix B Figure 1 for the avoidable health-related costs associated with tree planting and maintenance.

Green (and Cool) Roofs

Figure 6: Components of a Vegetated Roof (Hoverter, 2012)



A green roof is a rooftop designed to "support vegetation" (Dvorak & Volder, 2010). There are predominately two different types of green roofs: extensive and intensive green roofs. Extensive green roofs have less variety, are shallower in height and depth, and primarily serve as a filter for stormwater. Contrary to extensive green roofs, intensive green roofs have more variety and are designed to look more like a park (*Soil Science Society of America*, n.d.). Regardless of the type of green roof, regions who decide to implement them in mass usually follow a set of guidelines. The FLL German Roofing Guidelines, developed by German researchers in the 1970s, instruct policymakers to consider the "composition of the medium, its drainage characteristics, and the fertility requirements of plants", among other factors (*Soil Science Society of America*, n.d.). In **Figure 6**, one can see these components at work. In contrast to green roofs, cool roofs are less cumbersome to maintain. Cool roofs can be implemented in a variety of ways from painting a roof a lighter color to applying material that is more reflective than conventional roofs. The science behind how cool roofs work can be seen in **Figure 7**.

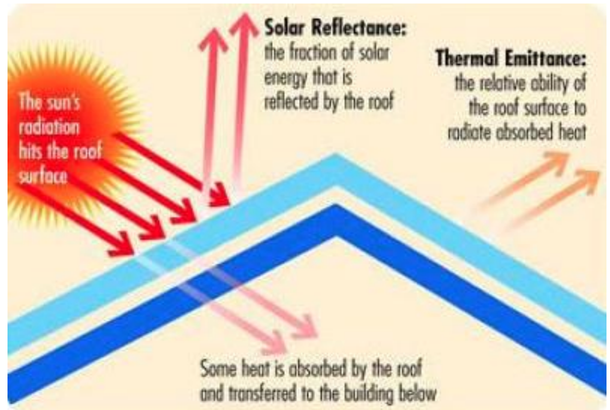
Despite these meaningful distinctions, some use the term "green roof" to describe any roof that aims to be more environmentally sustainable. Particularly, the Joint Committee on Roofing Materials and Systems of the International Council for Research and Innovation in Building and Construction recognizes green roofs as having three characteristics: 1) "[they] minimize the burden on the environment by using the Earth's resources responsibly; 2) conserve energy by improving the thermal efficiency of roofs; and, 3) extend roof lifespan by improving long-term performance" (Cavanaugh Laura M., 2008).

Advantages and Disadvantages

Both green and cool roofs have similar advantages and disadvantages. As is the case with increased shade, green and cool roofs can decrease energy use, specifically through air conditioners, decrease heat, and as a result, have an impact on the health of individuals who are most vulnerable to extreme heat. More directly, they can decrease the temperature of the roof itself, which has a direct impact on external heat (D. Li et al., 2014). One study in Philadelphia found green roofs to be as much as 65 degrees cooler than a traditional roof nearby (Hoverter, 2012). While cool roofs are less reliant on climate than green roofs, if maintained well, green roofs can have a longer life span than cool roofs (Wark, 2019).

Both green and cool roofs have installation barriers. Green roofs are limited in the types of roofs they can inhabit. To install a green roof, the building has to have a particular slope and be able to withstand a certain amount of weight from increased vegetation. Although cool roofs are similar to traditional roofs, when they need to be removed it is a significant undertaking in time and costs. Similarly, studies have found that both green and cool roofs might not provide as much cooling as originally thought (Hoverter, 2012).

Figure 7: The Science Behind Cool Roofs (*Cool Roofs*, n.d.)



Case Study Snapshot: Seattle, Washington's Green Area Ratio

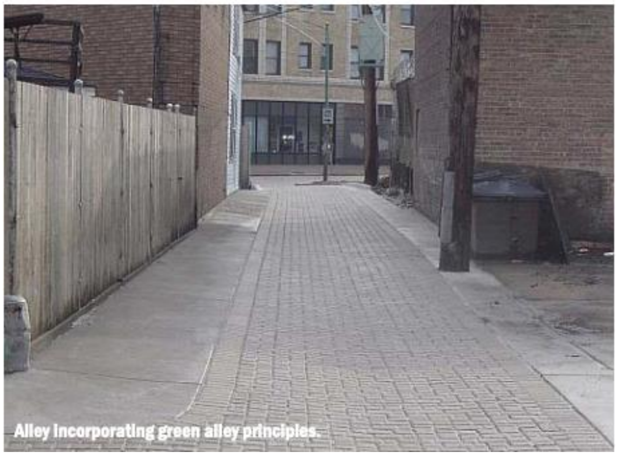
The Green Area Ratio is an urban sustainability metric that requires private properties to meet environmental infrastructure standards (Juhola, 2018). Seattle, Washington was the first city in the US to adopt this ratio and they call theirs the Seattle Green Factor (SGF). This score was established in the Seattle Municipal Code and only applies to new development. Per the guidance on their website, new development must "reach a minimum score… [depending] on the zoning of [the] property. You can choose from a "menu" of… credits for various features, including green roofs, rain gardens… [and] trees" (Seattle Green Factor—SDCI, n.d.).

Altering zoning code is the main policy mechanism used in this example. Seattle followed Berlin's lead in constructing a tool that fit their local policy context. While the effectiveness of this tool is still to be assessed, it is widely held that it aids the planner in increasing the "quantity and quality of green areas" (Juhola, 2018). As the American Society of Landscape Architects noted, "…because SGF significantly raises the bar for landscaping in affected zones, landscape design now starts in the initial stages of site planning, allowing more collaboration between design professionals; the resulting landscapes are more attractive and better integrated into site programs and amenity areas" ("Seattle Green Factor," 2017).

Green Streets

Most streets in urban settings are impervious. In other words, they are made up of material that stores heat and increases the temperature outside. In various cities, pavement represents the highest percentage of land cover, and is in part why “cool” pavement has been considered an option to address extreme heat (U.S. Environmental Protection Agency, 2012). Cool pavement has a broad definition. At first, when people referred to cool pavements, they referred to permeable surfaces. These surfaces allow air and water into holes in pavement to keep the surface cool when wet, and serve as a way to control stormwater runoff. However, as technology has advanced, cool pavements have come to include impervious surfaces as well that serve to cool the atmosphere (U.S. Environmental Protection Agency, 2012).

Figure 8: Impermeable Pavement vs. Green Alley (*Green Alleys*, 2017)



Advantages and Disadvantages

As is the case with other approaches, cool pavements directly affect the UHIE. They lower the outside temperature, decrease energy usage, and reduce greenhouse gas emissions and other air pollutants. In Los Angeles, through white-colored sealant, one road was found to be 23 degrees cooler (Oldfield, 2018). Cooling and cleaning the air impacts health outcomes. More so, cooler pavement can lead to increased driver safety because lighter surfaces better reflect street lights and drivers’ headlights in the evening (*Cool Pavements*, n.d.).

Nevertheless, implementing cool pavements is risky and highly context-dependent. Specifically, this intervention might not be as effective on its own, needing the supplement of shady areas to maximize its impact. Furthermore, there are potential unintended consequences. Recently, researchers in Los Angeles not only found that their cool pavements made people feel warmer, but the roads reflected 10 percent more sunlight that created a visible glare for drivers during rush hour (Bloch, 2019b). Moreover, they are costly to install and maintain (Hoverter, 2012).

Case Study Snapshot: Chicago, Illinois' Green Alley Project
In 2007, Chicago's Mayor, Richard Daley, following an advocacy push for a green roofs policy, announced that he wanted to pave 1,900 miles of alleyways with greener surfaces. This initiative became known as the Green Alley Project ("CHIGAGO'S NEXT LEAD," 2017). The three main focal points were to use permeable pavements to reduce stormwater runoff, use albedo (light-colored) pavement to address the UHIE, and to use recycled material to accomplish other environmental goals. In addition, they changed light fixtures in alleys to solely be directed downwards to use energy more efficiently. From 2001 to 2017, 300 green alleys were installed (Green Alleys, 2017). The transition from an impermeable alley to a green one can be seen in Figure 8.

For cities across the country who are engaging in this type of project, it has been found that these programs are most effective if they are based in city departments, with responsibilities to enhance and maintain public infrastructure, or led by local non-governmental organizations (Newell et al., 2013). Local governments have a lot of control over paving their roads, so this policy instrument takes into account an aspect of green infrastructure for which cities have a lot of control. Nonetheless, in the case of Chicago, there was found to be little to no cooling effect on the surrounding environment. Cooling pavements were found to be too small of an influence on the environment without taking into account the larger context (Coseo & Larsen, 2015).

Summary of Approaches Table

Approach	Local Government Instruments	Impact
Green growth • Trees • Vegetation	• Strategic plans • Tree ordinances • Community engagement	• Cools nearby roofs and walls by 20-40 degrees
Green roofs • Green roofs • Cool roofs	• Strategic plans • Zoning regulations • Building code regulations • Community engagement	• Up to 65 degrees cooler than traditional roofs
Green streets • Albedo roads	• Strategic plans • Pilot projects • Community Engagement	• Cools outdoor air temperatures by as much as 23 degrees

Limitations of Approaches

Studies in neighborhoods in Los Angeles, CA, Portland, OR, and Richmond, VA have all demonstrated that the effectiveness of approaches depend on the setting. In Los Angeles, with all things held constant, additional street trees and cool pavements resulted in reducing temperature, and cool and green roofs cooled the atmosphere around the pedestrian level. However, in already shaded locations, cool pavements were the most effective at reducing temperature (Taleghani et al., 2016). In Portland, a study looked at the effectiveness of six different cooling interventions (i.e. increased trees, cool roofs, cool pavements, etc.) across six different types of land use patterns (i.e. fully industrialized, partially shaded with trees, fully shaded with trees). They found inconsistent results across landscapes, and although each intervention proved effective at decreasing temperature on their own, "one mitigation solution alone would not significantly reduce extreme heat" (Makido et al., 2019). Richmond's study, which looked at three interventions across three areas came to similar findings, including the positive externalities that come from interventions in adjacent neighborhoods (CAPA Strategies, LLC, 2019).

These findings highlight the difficulty city governments have in addressing the UHIE. While it is encouraging to see the effectiveness of individual interventions, given the urgency of the issue, deep impact is only made with a comprehensive approach. This presents obstacles for city government in several areas. First, more initiatives often mean needing more personnel and financial resources. Cities have limited budgets as is, not to mention for issues related to sustainability. Additionally, a more comprehensive approach takes time to create and implement. From strategic planning to coordination across agencies, there are opportunity costs along with monetary costs. Lastly, cities face constraints based on federal and state policy. Although Richmond has a "strong" mayoral system, the Dillon Rule in Virginia requires certain actions to be done or approved by the state first, which can present obstacles to policy adoption and implementation.

Criteria

OVERVIEW

Effectiveness, equity, costs, and feasibility are the criteria used to evaluate policy options. Effectiveness and equity will be rated low (decreases temperature by 0 to 1 degree F), medium (decreases temperature by 2 to 4 degrees F), or high (decreases temperature by 5 to 10 degrees F). Where data is available, costs will be determined. Feasibility will be broken down into two sub-categories: political and administrative. Each will be rated as very difficult, difficult, neutral, easy, or very easy. All criteria will be weighted equally.

1. Effectiveness

This criterion measures the extent to which a policy option will reduce heat in Richmond. Heat can be measured through a variety of tools. There are tools that measure the temperature, while others, such as ones that measure the heat index, take temperature and humidity into account. Instruments that measure heat index collect a more accurate measurement of one's experience with weather. Looking at heat index is crucial because heat can be felt differently based on the level of humidity in the air.

2. Equity

This criterion considers how effective an intervention would be for particular populations. Particularly, how effective is a policy option at reducing heat in neighborhoods harmed the most by extreme heat? Thus, as with effectiveness, I will be looking at how options will reduce heat, adding on the layer of whether or not the option primarily and effectively reduces heat for those living in and near the Diamond, Highland Terrace, Newtown West, and Old Town Manchester.

3. Costs

Costs concern the monetary and opportunity costs of an option. I will look primarily at labor costs, since each option is primarily concerned with crafting documents with varying levels of legal status. My labor calculations will take opportunity costs, salary, and benefits into account.

4. Political Feasibility

Political feasibility will explore *who* needs to be involved for an option to be successfully implemented. If an option can be pursued through the Mayor's Office without the permission of other stakeholders, it will be more feasible than options that will need the cooperation of City Council, the state legislature, or beyond. Given the urgency of this issue, timing is a pivotal component to success.

5. Administrative Feasibility

Administrative feasibility will concern *how many* people need to be involved for an option to be successfully implemented. If an option can be pursued through the personnel already present in the Mayor's Office, local government, relevant organizations, and community members, it will be more administratively feasible. Again, given the urgency of this issue, how long it will take to recruit or train people to act will also be a pivotal indicator for success.

Policy Options

1. Revise Richmond's tree ordinance.

The first option is for the Urban Forestry Division to revise Richmond's tree ordinance. This is a legally binding intervention to address the UHIE that needs to be passed by City Council. Since Richmond's tree ordinance was last updated in 1992, renewing this ordinance would give the city the opportunity to update their planting, pruning, and overall maintenance statutes. Generally, there are three types of ordinances: street tree, tree protection, and view ordinances. Street tree ordinances are concerned with the planting and removal of trees in public rights-of-way. Tree protection ordinances provide protection for native or historical trees in an area. View ordinances help private owners resolve disputes about how trees might block particular views (Bernhardt & Swiecki, 1999). This option is not referring to one type over another, but encourages the Urban Forestry Division to take local context into consideration when crafting it.

Experts urge localities to consider a number of factors when crafting an effective ordinance. For example, the National Arbor Day Foundation recommends localities to include an "Authority and Power" section. This would ensure "someone within city government [has] the clearly designated authority to administer the provisions of the ordinance" (Fazio, 1990). They recommend 16 particular sections in total. From clearly stating goals to developing the ordinance with community support, the California Department of Forestry and Fire Protection Urban Forestry Program (CDF) recommends seven principles to follow in general to create an effective ordinance (Bernhardt & Swiecki, 1999). As is seen in Charlotte, NC, Athens-Clarke County, GA, and San Antonio, TX, there are many ways to achieve these goals, and Richmond would do well to look at a number of different ordinances to guide their revision process.

Policy Option 1 Evaluation

Effectiveness: Medium

Revising a tree planting ordinance results in a **medium** effectiveness rating. According to a recent study, at the scale of a typical city block, it takes at least 40 percent canopy coverage to counteract the warming effect of asphalt. In particular, with three-quarters of a block covered by impervious surfaces, reaching 40+ percent canopy coverage could lead to a decrease in 2.5+ degrees C (4.5 to 9 degrees F). On average, you would see a difference in 0.5 to 1 degree C (.9 to 1.8 degrees F) (Ziter et al., 2019). In Richmond, it is feasible to reach 40+ percent canopy coverage in the areas affected most by extreme heat in five to ten years. Nevertheless, as has been shown in aforementioned studies, a comprehensive approach is most effective in curbing the UHIE.

Equity: Medium

This option has a **medium** equity rating. This is especially the case if the ordinance is designed to target areas affected most by the UHIE, as is being done in Dallas (Walker, 2019) and Detroit (*Detroit Sustainability Action Agenda*, 2019). Again, the most effective approach is a comprehensive one that is targeted towards supporting these particular areas.

Costs: $2,278.56 - $9,114.24[5]

Since ordinances take several months to one year to create, I have low and high cost estimates. It would require **48-192** personnel hours and **48-192** volunteer hours.[6]

Political Feasibility: Difficult

This option is **difficult** in political feasibility. Along with the high demand for green initiatives in the city, there is high demand for an updated tree policy. Nonetheless, key aspects to implementation, such as hiring two arborists within the Urban Forestry Division, has had difficulty being accepted by City Council in the past.

Administrative Feasibility: Neutral

This option is **neutral** in administrative feasibility. Despite being understaffed in arborists, and having to balance many opinions while seeking community input, difficulty in implementation is counterbalanced by the slew of community partners and programs to assist with the planting and maintenance of trees, as has been seen by the city's tree planting fund.

Pros: Binding document that can keep city accountable to equity goals; if implementation plan is in place can lead to significant benefits

Cons: Given limited capacity, could require too much time from personnel that is already being taken up by master plan process; given history, could also be politically infeasible

[5] See Appendix C Figure 1 for cost calculations.

[6] See Appendix D Figure 2 for more holistic cost calculations over the course of 10 years.

2. Utilize the master planning process to propose a package of zoning regulations.

The second option is to utilize the master planning process to propose a package of zoning regulations. This is also a legally binding instrument that needs to be referenced in a master plan and then passed by City Council. Namely, this option calls for the crafting of a Green Area Ratio (GAR) zoning regulation and a Floor Area Ration (FAR) bonus. The GAR zoning regulation is a means to require new development to meet certain green architecture requirements. This could include planting trees, and/or installing cool/green roofs, green walls, or various green architecture. While a FAR bonus can take many forms, most incentivize developers to expand green roofs by offering more space to develop laterally or horizontally. Both would complement Richmond's C-PACE program, which allows property owners to take out loans to pay for clean energy improvements for current and/or new buildings (Spiers, 2019). Both could be targeted in the areas most impacted by the UHIE.

Reforming building and zoning codes is one instrument at the Mayor's disposal to enact change, and the master planning process is a unique moment in time to set up such changes. As previously mentioned, master plans are the first step in the process in making any land use changes. Following this, coding changes need to be passed by City Council. The Center for Watershed Protection created a guide to assess how municipal codes affect an urban forest (Swann, 2018). Portland, OR (33.510 Central City Plan District, 2018), Seattle, WA (*Seattle Green Factor—SDCI*, n.d.), and Austin, TX (Downtown Density Bonus Program, n.d.) have created exemplary GAR and FAR zoning regulations.[7]

Policy Option 2 Evaluation

Effectiveness: Low

The effectiveness of this alternative is **low**. The literature shows decreases in temperature from this zoning initiative, mostly from green roofs (W. C. Li & Yeung, 2014). Toronto's Eco-roof Incentive Program is projected to have resulted in a decrease of a few degrees in local temperature (*Case Study: City of Toronto's Eco-Roof incentive Program and Green Roof Bylaw*, 2018). Furthermore, as seen in Seoul, there were drops in land surface temperature in higher-density land use areas (J.-I. Kim et al., 2019). Yet, there are few studies that evaluate GAR and FAR zoning regulations as comprehensive policy tools for change. D.C. and Seattle are contemporary examples, but Berlin, Germany has utilized this instrument since 1997. While a comprehensive study cited the zoning effort contributing to Berlin's clean air quality, others point to the effects of car restriction zones and policies that encourage commuting by foot, bicycle, and mass transit (Gardner, 2012).

[7] Additional examples can be found [here](#).

Equity: Low

The equity of this alterative is **low**, because while it might impact future development in places like Scott's Addition, a large amount of development is not occurring in the other areas most impacted by extreme heat. Current and future projections for development in Richmond are in areas that are not affected by the UHIE (Smith, 2018).

Costs: $3,417.84 - $13,671.36[8]

Since zoning regulations also take several months to one year to create, I have low and high cost estimates. It would require **72-288** personnel hours and **72-288** volunteer hours.

Political Feasibility: Neutral

This option is politically **neutral**. There is heightened support for changes in code and the C-PACE program is an ambitious initiative that created precedent. Nonetheless, developers are also stakeholders. These proposed changes could be seen as obstacles to development which could make this a more complicated political option.

Administrative Feasibility: Easy

Due to model regulation from a variety of contexts, and the fact that the burden of work is put on the developer rather than local government, this option is administratively **easy.**

Pros: There is a blueprint for these codes elsewhere; administratively easy for local government

Cons: Does not target most vulnerable neighborhoods affected by UHIE

[8] See Appendix C Figure 2 for cost calculations.

3. Create an urban forestry management plan.

The third option is to create an urban forestry management plan. This option is not legally binding. It is different than an ordinance in that it is wider in scope, providing a vision, specific recommendations, implementation steps, and a plan to monitor progress and reset goals accordingly. It is also wider in scope and more specific in its recommendations than a master plan. Although not legally binding, urban forestry plans provide the foundation for communities to establish their goals, plans, and capacity for all urban forest activities.

According to the "Urban Forest Management Plan" toolkit, an effective urban forest management plan includes the following: "[a] vision for the urban forest, inventories and assessments of the current status, a strategic plan (goals, objectives, and actions) based on the information analyzed, [an] implementation plan with… dates and responsibilities, [and a] monitoring plan with a system…to check effectiveness and revise…as needed" (*Urban Forest Management Plan Toolkit*, 2018). Pittsburgh, PA's plan (*Pittsburgh Urban Forest Master Plan*, 2012) is considered the gold standard, while Cleveland, OH (*The Cleveland Tree Plan*, 2015) and Austin, TX (*Austin's Urban Forest Plan*, 2013) are also referenced as archetypes.

Policy Option 3 Evaluation

Effectiveness: Medium

The effectiveness of this option is **medium**. Although urban forestry plans do not have the force of law, they are not bound by a legislative process or body either. Effective plans take time to develop, but this flexibility enables neighborhoods to create a plan on their own timeline in response to the urgency of the issue. Additionally, plans are flexible in topic as well. Instead of committing to one intervention, plans can incorporate many at once. As previously mentioned, a more comprehensive approach is needed to make a meaningful impact on the issue.

Equity: Medium

The equity of this alternative is **medium**. As with tree ordinances, an urban forestry plan can ensure that actions are targeted towards communities who are hurt most by the UHIE. This has the potential to lead to significant impact for these communities, but as for the effectiveness category, because it is not legally binding, it does not guarantee interventions are implemented.

Costs: $17,136.00 - $34,272.00[9]

An urban forestry plan would take six months to a year to create. I have low and high cost estimates that align with this time frame. It would require **240-480** personnel hours and **480-960** volunteer hours.

Political Feasibility: Easy

This option is rated as politically **easy**. As previously mentioned, there is interest in green initiatives. On top of that, there is no need for formal approval from a legislative body. Hence, these features make it easier to implement politically.

Administrative Feasibility: Easy

This option would be evaluated as administratively **easy.** Given the number of community organizations invested in developing Richmond's urban forest, and momentum that can be built from the current master planning process, interested and able personnel should not be an issue for this type of project.

Pros: Opportunity to draft a comprehensive approach; easy administratively and politically

Cons: Not legally binding; how long it takes to create and implement is mostly up to the task force that oversees the plan

9 See Appendix C Figure 3 for cost calculations.

Outcomes Matrix

Options	Effectiveness	Equity	Costs	Political Feasibility	Administrative Feasibility
1) Revise Richmond's tree ordinance.	Medium	Medium	$2,278.56 to $9,114.24	Difficult	Neutral
2) Utilize the master planning process to propose a package of zoning regulations.	Low	Low	$3,417.84 to $13,671.36	Neutral	Easy
3) Create an urban forestry management plan.	Medium	Medium	$17,136.00 to $34,272.00	Easy	Easy

Recommendation

I recommend **Policy Option 3: Create an urban forestry management plan**. Given the urgency of the issue at hand, this option would be the easiest to implement, and potentially the quickest. Instead of just relying on expanding Richmond's tree canopy, creating zoning regulations, or implementing other green architecture, creating an urban forestry management plan sets the foundation for a comprehensive approach to cooling the UHIE. Since every department and agency in the city is focused on planning Richmond's next 20 years, it is also timely. Thus, there is also the opportunity to frame this plan within the context of Richmond's larger sustainability plan.

Limits of Recommendation

Nevertheless, there are limitations to this recommendation. By definition, it pauses action. Any time one decides to assess and plan, they run the risk of an urgent issue becoming worse. Secondly, a plan of this nature is not legally binding. It will take intentional agreements and structures put in place to ensure this plan is not only created, but updated on a regular basis. These shortcomings and more are addressed in the implementation plan.

Implementation

OVERVIEW

Although one recommendation is proposed, creating an urban forestry management plan uniquely opens up the opportunity to embed the other options, not to mention other interventions to address the UHIE. Nonetheless, this section presents options for a working group to consider. The implementation recommendations fall into three overall steps: 1) Recruit diverse stakeholders for an urban forestry management plan task force, 2) Create an urban forestry management plan, and 3) Conduct a tree-planting pilot project.

1. Recruit diverse stakeholders for an urban forestry management plan task force.

Run by the Office of Sustainability, a task force of city officials, non-profit professionals, residents in communities impacted most by the UHIE, and business owners should be established to create an urban forestry management plan. This should include approximately five city employees and 10 volunteers. The Office of Sustainability, which currently has six staff members, should assemble it to ensure the plan is aligned with their overall sustainability plan and RVAgreen 2050. The Richmond 300 Environment Working Group and the recently assembled "Green Team" are also great groups from which to recruit. Building a task force will not only build greater buy-in among community members, but diverse groups are more effective. Special attention should be put towards creating long-term partnerships, which can turn into a permanent Urban Forestry Advisory Council (public-private partnership), much like DC created through their Tree Canopy Protection Act of 2016 (*Urban Forestry Advisory Council | ddoe*, n.d.).

Among those recruited, one stakeholder should become **an anchor institution that can commit to combatting the UHIE for the long-term.** An anchor institution serves as a sustainable leader among other partners in the work to continue communication, and monitor and track progress. They also typically are trusted within the community, and have funds and staff (*Build a Stakeholder Coalition*, 2020). Hence, although I recommend for the Office of Sustainability to convene the group, this role does not have to be played by them. VCU or the Science Museum of Virginia may be well-suited for this role. Examples of different types of anchor institutions include regional planning organizations, non-profit organizations, universities, and hospitals. Anchor institutions do not only increase the likelihood of long-term community investment, but financial investment (Pease, 2016).

2. Create an urban forestry management plan.

The task force's main objective will be to create an urban forestry management plan. Wisconsin's Department of Natural Resources Division of Forestry encourages task forces to answer four questions while developing their plan: "1) What do you have? 2) What do you want? (feedback) 3) How do you get what you want? 4) Are you getting what you want?" (Wisconsin Department of Natural Resources Division of Forestry, 2011).

As aforementioned, these plans do not only create clear goals and standards for tree planting and maintenance, but define a comprehensive strategy to increase greenery in a city. In addition to guidance previously mentioned, it is also crucial to incorporate risk mitigation planning. This includes, but is not limited to, identifying diverse funding streams (i.e. endowments, community foundations, fines), and anticipating climate- and population-related change.

This plan should consider the following action steps:

- **Create a one to two page section for the Richmond 300 master plan, highlighting the need for a more robust urban forestry program.**[10] The master planning process is a great opportunity to ensure trees and green frameworks are included in the work of other agencies. Highlighting the need for Richmond to create a more robust urban forestry program adds extra accountability to all involved to systematically review and revise its urban forestry management plan. Similarly, the task force can recommend frameworks for other agencies to include in their plans.[11]

- **Create a canopy map and inventory of trees.** STRATUM'S sample survey of Richmond's street trees (Girardi, 2009), the Urban Tree Canopy Analysis of Virginia Localities (McKee, 2010), and the most recent tree inventory *(Tree Inventory, City of Richmond, Virginia, Public Works*, n.d.) give a wide-ranging picture of Richmond's urban tree canopy, but are slightly outdated. It is generally recommended to work with data that is at most four years old. Thus, it is recommended to revisit this issue to determine whether or not updating this data should be a priority in the strategic plan.

- **Identify areas most impacted by the UHIE.** Thanks to the great work by Dr. Hoffman and others, Richmond has a recent (2017), clear idea of the areas impacted most by the UHIE. Furthermore, through work done in their Richmond 300 working group, Hoffman and Mullen have identified 10 priority parcels within the neighborhoods impacted most that make most sense to address first. The group should confirm that this approach assists those most threatened by the UHIE.

[10] This would also be the place to reference zoning regulations, should the task force decide they want to go in that direction.
[11] See Appendix D Figure 1 for a chart of agencies and how they intersect with urban forestry.

- **Create a tree planting ordinance.** Tree ordinances have the potential to maximize trees' potential in a community by providing planting and maintenance guidance with the force of law. As has been mentioned, Richmond's current ordinance was adopted in 1992 and needs to be updated. The U.S. Forest Service recommends to connect planting trees with "community development practices", and to ensure maintenance is enforced (*Ten-Year Urban Forestry Action Plan: 2016-2026*, 2015). The task force should consider embedding this effort into their plan.

- **Maintain current and future trees.** Two-thirds of costs of planting a tree come from maintenance. Currently, the highest amount of 311 calls are related to requests for tree maintenance. Furthermore, a city does not see the benefits it could see in the long-run without maintaining its trees (Ten-Year Urban Forestry Action Plan: 2016-2026, 2015).[12] Thus, the task force should have a clear plan for maintenance as well as for planting. For instance, filling the two arborist vacancies is crucial for the long-term success of Richmond's trees.

- **Monitor progress to goals.** There should be a plan in place to restart urban forestry work and monitor its progress. For example, the progress of the program should be reviewed by representatives from the anchor institution every three years, at minimum. They should measure the progress of all goals, including, but not limited to, tree-planting, tree maintenance, and any other initiative that seeks to cool the city. This report can then be submitted to the task force to review and revise plans as necessary.

- **Create an advocacy plan.** An advocacy plan thinks about the best ways to frame the topic for the public to build social capital to increase the likelihood of successful implementation. Although there will be diverse stakeholders on the task force, there are other individuals and organizations that need to be engaged for the long-term success of the urban forestry program. They include City Council members, leaders in other departments and agencies, residents in affected neighborhoods, universities, hospitals, business owners, new developers, and more. Power mapping[13] can help identify who would be best to partner with and who makes most sense to recruit to support one's initiatives. Seattle's urban forestry communication toolkit (Partners, 2014) can aid with framing the work in impactful ways.

[12] See Appendix D Figure 2 for cost calculations.

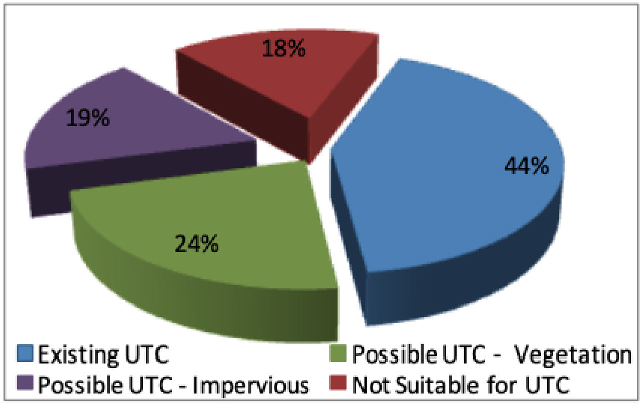
[13] See Appendix D Figure 3 for a power mapping template.

3. Conduct a tree-planting pilot project.

A pilot project simultaneously responds to the urgency of the issue and demonstrates the effectiveness of one of the most effective approaches to addressing the UHIE. Some communities have made it a competition, while others have organized yard tree giveaway events ("Urban Forestry Completes Pilot Year for Yard Tree Giveaway," 2017). Run by members of the task force, trees should be planted by residents and volunteers in one of the 10 parcels identified by the working group. Melbourne was successful in running a pilot project on a single street (McMahon, 2015). Parks, parking lots, and roadside verges (*Urban Tree Planting Opportunities*, 2016) should be considered for locations for the biggest impact. Finally, the project should follow steps for successful planting and future maintenance (*Successful Tree-Planting Projects and Events*, 2015).

Appendix A: Background

Figure 1: Further Details on the disparities related to the UHIE in Richmond, VA (McKee, 2010)



As last measured, in 2010, Richmond has 42 percent canopy coverage of all land areas within the city. This is comparable to coverage in Arlington, Fairfax County, and Chesapeake. When measured in property parcels, Richmond has approximately 44 percent existing urban tree canopy (UTC), and approximately 42 percent possible UTC (McKee, 2010). Of the 42 percent possible UTC, approximately 23 percent are on surfaces with vegetation, and 18 percent on impervious surfaces.

Nonetheless, there is great disparity in UTC across zones. The lowest UTC exists in zones 9 (Westover Hills/Forest Hill/Woodland Heights), 8 (Bellemeade), 4 (Newtowne/Carver/Jackson Ward), and 7 (Maymont/Byrd Park/Oregon Hill/Carillon).

The zip codes that are the hottest in Richmond are 23230 (the Diamond, Scott's Addition Historic District), 23220 (the Fan District, and parts of Jackson Ward), 23219 (Biotech, MCV, and Central Office Districts, and Downtown Shockoe Slip) and 23224 (Old Town Manchester, and parts of South Richmond).

Figure 2: Environmental Risk Factors by HOLC Neighborhood Grades for All HOLC Cities (Nelson, n.d.)

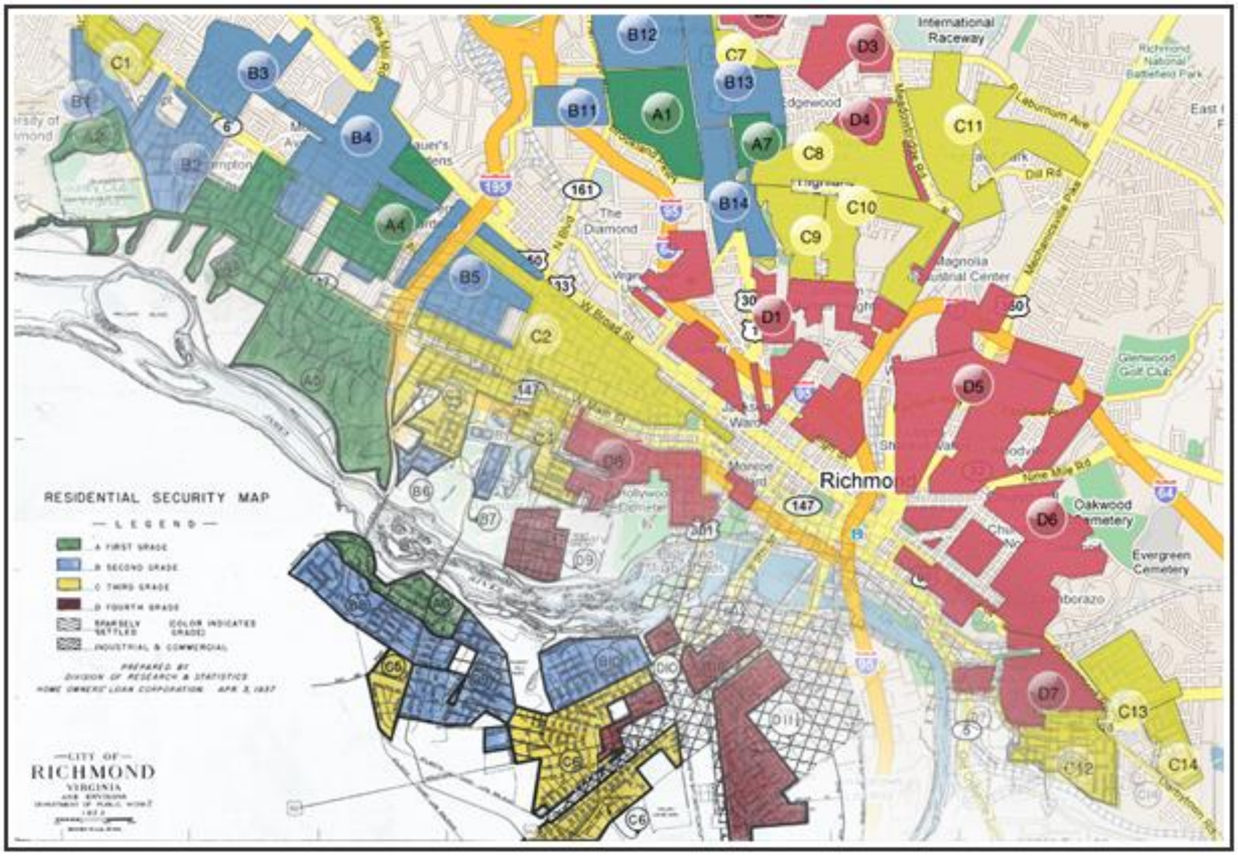
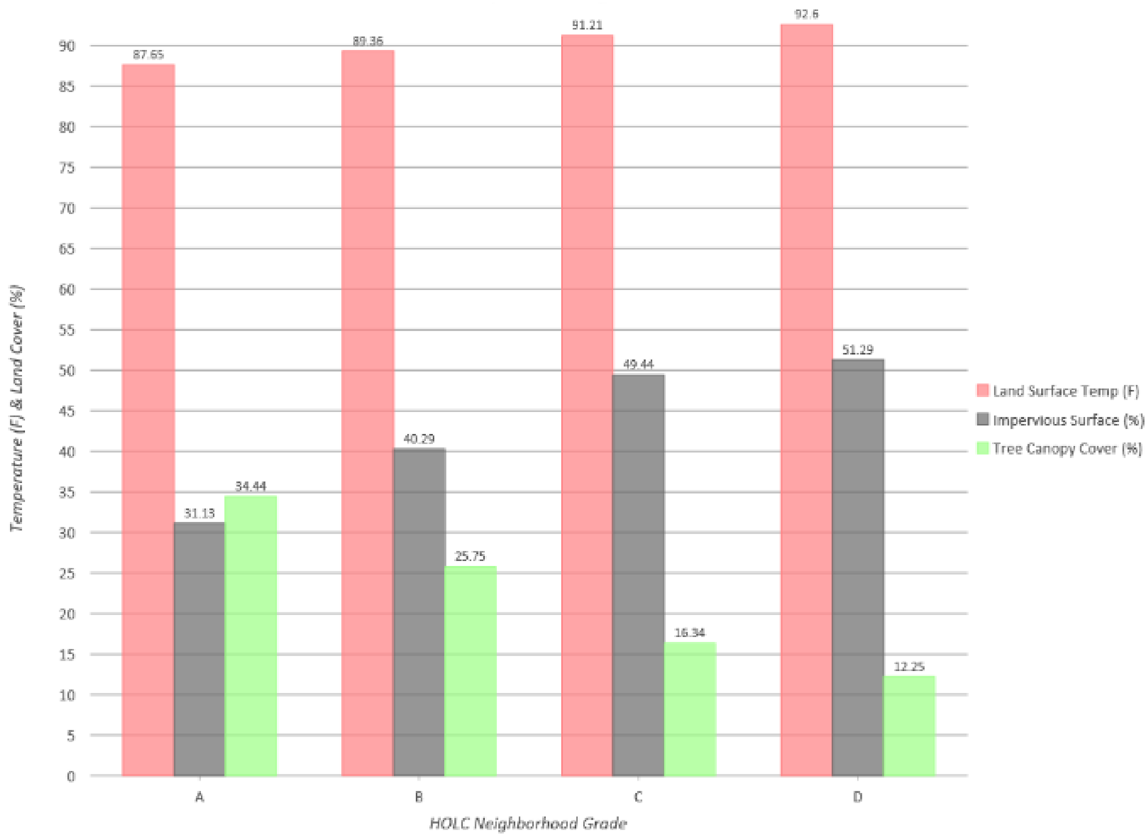
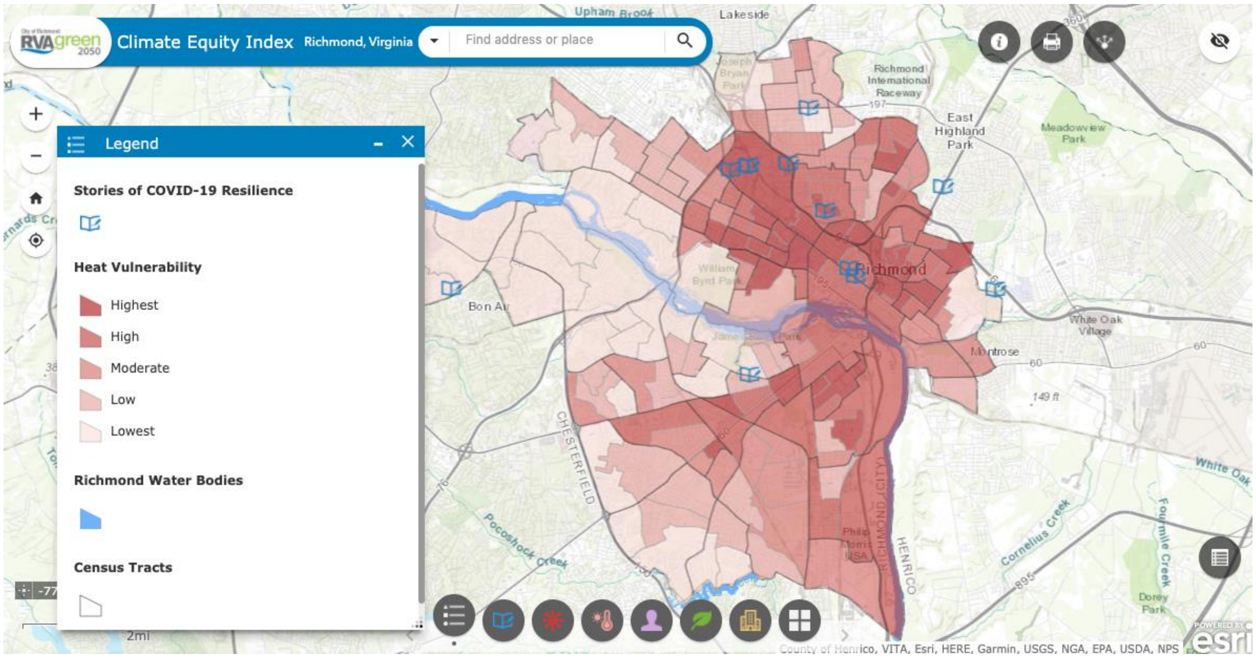


Figure 3: Environmental Risk Factors by HOLC Neighborhood Grades for All HOLC Cities (*Groundwork RVA: Climate Safe Neighborhoods*, n.d.)



Land Surface Temperature and Impervious Surface increase as HOLC neighborhood grade decreases while tree canopy increases with neighborhood grade.
(*Source: NLCD & Landsat 8 data summarized by HOLC grade by Groundwork Milwaukee.*)

Figure 4: Hottest Neighborhoods by Census Tract (*Climate Equity Index*, n.d.)



Appendix B: Best Practices

Figure 1: Annual Avoidable Health Related Costs Associated with Tree Planting and Maintenance (McDonald et al., n.d.)

Adjusted COBRA Model, $2015					
City	**City Population**	**TNC Tree Planting and Maintenance Cost ($)**	**Health Care Cost ($)**		**Work Loss Cost ($)**
			High	**Low**	
Atlanta	464,000	5,785,000	221,000	57,000	120,000
Austin	932,000	5,411,000	533,000	138,000	450,000
Baltimore	621,000	3,987,000	458,000	139,000	188,000
Boston	667,000	2,336,000	229,000	56,000	123,000
Bridgeport	144,000	821,000	44,000	11,000	15,000
Chicago	2,696,000	11,592,000	875,000	219,000	353,000
Dallas	1,300,000	8,871,000	1,172,000	306,000	727,000
Denver	600,000	4,382,000	111,000	28,000	81,000
Detroit	677,000	9,568,000	373,000	88,000	108,000
Houston	2,099,000	15,320,000	1,844,000	488,000	1,177,000
Los Angeles	3,972,0001	20,340,000	3,034,000	797,000	1,973,000
Louisville/Jefferson County	760,000	10,111,000	937,000	223,000	288,000
Miami	399,000	1,885,000	564,000	136,000	223,000
Minneapolis	383,000	3,389,000	182,000	44,000	118,000
Nashville-Davidson	679,000	16,433,000	384,000	88,000	165,000
New Orleans	390,000	2,261,000	147,000	37,000	72,000
New York	8,550,000	34,047,000	6,268,000	1,807,000	3,713,000
Philadelphia	1,567,000	6,858,000	990,000	276,000	434,000
Phoenix	1,446,000	5,297,000	68,000	18,000	40,000
Pittsburgh	304,000	4,185,000	194,000	48,000	76,000
Portland	584,000	4,416,000	238,000	53,0000	154,000
Sacramento	466,000	3,375,000	345,000	77,000	179,000
San Diego	1,395,000	6,228,000	677,000	174,000	470,000
San Francisco	865,000	5,967,000	295,000	77,000	254,000
San Jose	1,027,000	2,011,000	255,000	60,000	174,000
Seattle	609,000	3,365,000	149,000	32,000	120,000
Washington DC	681,000	3,217,000	274,000	70,000	148,000
Overall	**34,278,000**	**201,460,000**	**20,860,000**	**5,554,000**	**11,941,000**

Appendix C: Options

Figure 1: Policy Option 1 Cost Calculations

Assumptions:

- Median wage for general population is $23.93 (for first quarter of 2020)[14]
- Median wage for City of Richmond employees is $23.54 (salary = $48,954.19)[15]
- 2 local government employees
- 2 volunteers

Low Estimate Calculations (3 months):

- Employees: 2 hours per week over 3 months = 24 hours x 2 employees = 48 hours
- Cost of 48 hours of work for 2 employees = $1,129.92
- Volunteers: 2 hours per week over 3 months = 24 hours x 2 volunteers = 48 hours
- Opportunity cost of 48 hours of work for 2 volunteers = $1,148.64
- $1,129.92 + $1,148.64 = $2,278.56

Total Low Estimate Cost = $2,278.56

High Estimate Calculations (12 months):

- Employees: 2 hours per week over 12 months = 96 hours x 2 employees = 192 hours
- Cost of 192 hours of work for 2 employees = $4,519.68
- Volunteers: 2 hours per week over 12 months = 96 hours x 2 volunteers = 192 hours
- Opportunity cost of 192 hours of work for 2 volunteers = $4,594.56
- $4,519.68 + $4,594.56 = $9,114.24

Total High Estimate Cost = $9,114.24

Cost Range = $2,278.56 - $9,114.24

[14] The median weekly earnings from the first quarter of 2020 are used for calculations, found here.
[15] The median salary of City of Richmond employees as last reported on March 15, 2019 are used for calculations, found here.

Figure 2: Policy Option 2 Cost Calculations

Assumptions:

- Median wage for general population is $23.93 (for first quarter of 2020)
- Median wage for City of Richmond employees is $23.54 (salary = $48,954.19)
- 3 local government employees
- 3 volunteers

Low Estimate Calculations (3 months):

- Employees: 2 hours per week over 3 months = 24 hours x 3 employees = 72 hours
- Cost of 72 hours of work for 3 employees = $1,694.88
- Volunteers: 2 hours per week over 3 months = 24 hours x 3 volunteers = 72 hours
- Opportunity cost of 72 hours of work for 3 volunteers = $1,722.96
- $1,694.88 + $1,722.96 = $3,417.84

Total Low Estimate Cost = $3,417.84

High Estimate Calculations (12 months):

- Employees: 2 hours per week over 12 months = 96 hours x 3 employees = 288 hours
- Cost of 288 hours of work for 3 employees = $6,779.52
- Volunteers: 2 hours per week over 12 months = 96 hours x 3 volunteers = 288 hours
- Opportunity cost of 288 hours of work for 3 volunteers = $6,891.84
- $6,779.52 + $6,891.84 = $13,671.36

Total High Estimate Cost = $13,671.36

Cost Range = $3,417.84 - $13,671.36

Figure 3: Policy Option 3 Cost Calculations

Assumptions:

- Median wage for general population is $23.93 (for first quarter of 2020)
- Median wage for City of Richmond employees is $23.54 (salary = $48,954.19)
- 5 local government employees
- 10 volunteers

Low Estimate Calculations (6 months):

- Employees: 2 hours per week over 6 months = 48 hours x 5 employees = 240 hours
- Cost of 240 hours of work for 5 employees = $5,649.60
- Volunteers: 2 hours per week over 6 months = 48 hours x 10 volunteers = 480 hours
- Opportunity cost of 480 hours of work for 10 volunteers = $11,486.40
- $5,649.60 + $11,486.40 = $17,136.00

Total Low Estimate Cost = $17,136.00

High Estimate Calculations (12 months):

- Employees: 2 hours per week over 12 months = 96 hours x 5 employees = 480 hours
- Cost of 480 hours of work for 5 employees = $11,299.20
- Volunteers: 2 hours per week over 12 months = 96 hours x 10 volunteers = 960 hours
- Opportunity cost of 960 hours of work for 10 volunteers = $22,972.80
- $11,299.20 + $22,972.80 = $34,272.00

Total High Estimate Cost = $34,272.00

Cost Range = $17,136.00 - $34,272.00

Appendix D: Implementation

Figure 1: Different Agencies Involved in Comprehensive Planning Process (*Build a Stakeholder Coalition*, 2020)

Agency	Where do they fit in?	What can they do?	What do they get out of it?
Parks	Recreation, Outdoor Experiences	Plan for tree canopy	Many benefits, including improved public health
Public Works	Stormwater management	Include trees in GI plans	Reduced flow, pollutant reduction
Planning	Zoning, Development	Maximize green space, minimize development impact [LID]	More tree canopy creates healthy, vibrant neighborhoods
Transportation	Roads, street and sidewalk design	Complete and green streets	Vibrant, safe neighborhoods and stormwater management
Public Health	Promote healthy places	Assure people in "health hotspots" have access to nature	Improved health outcomes for many chronic conditions
Sustainability Office	Climate adaptation and mitigation	Commit to trees as solutions to problems [e.g. UHIs, energy use]	Greener, healthier, more resilient communities
Regional Planning Organization	Often the hub for future-oriented planning	Convene like-minded officials from member municipalities	Stronger foundation for effective region-wide [and watershed level] action

Figure 2: Tree Planting and Maintenance Cost Calculations

General Tree Cost Calculations

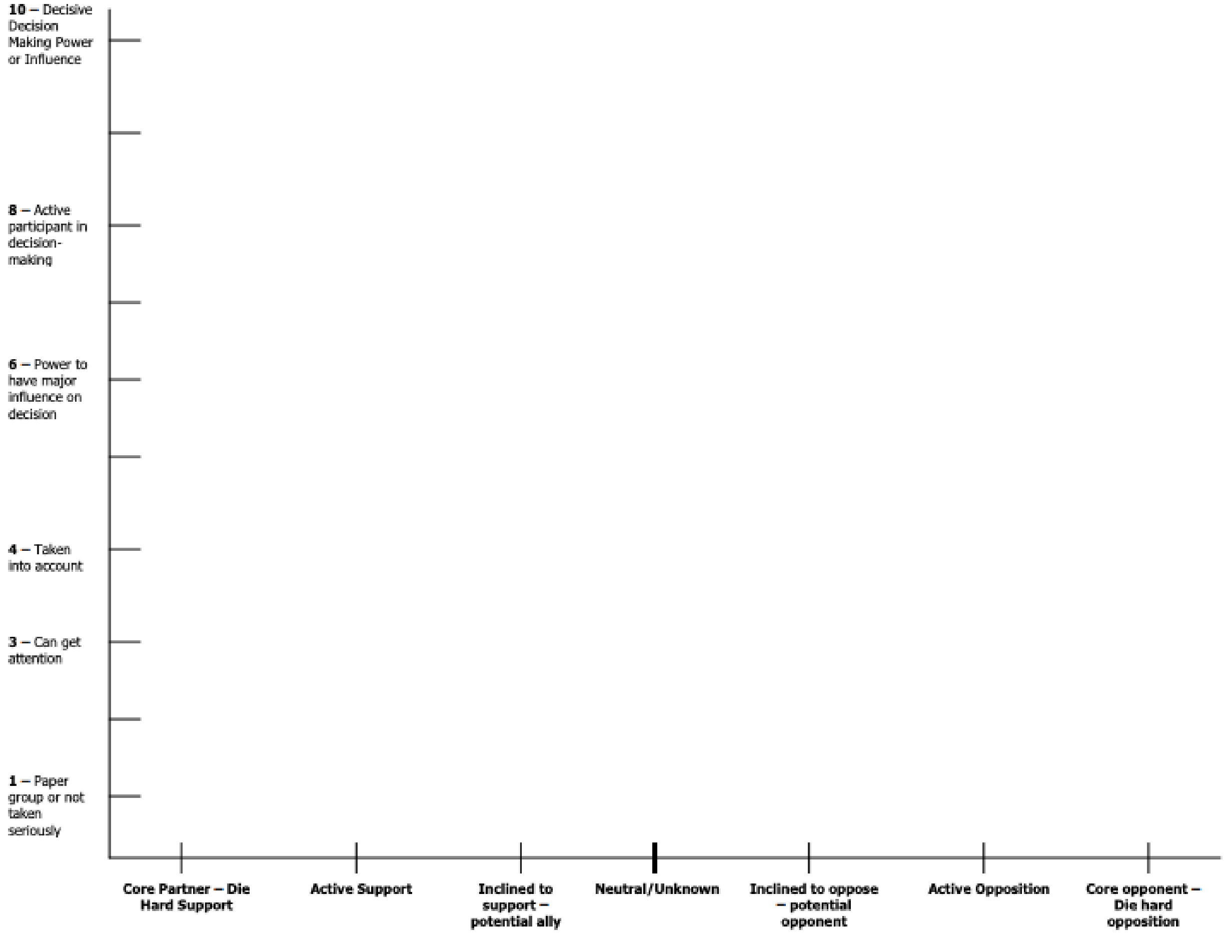
Annual costs can range from $15 per tree in the Desert Southwest region to $65 per tree in California. Pruning is often the greatest expenditure, accounting for 25 to 40 percent of total annual costs (about $4 to $20 per tree). Administration and inspection costs are the next largest expenditure, accounting for 8 to 35 percent of total annual costs (about $4 to $6 per tree). Planting only accounts for about 2 to 15 percent of total costs (about $0.50 to $4 per tree). Benefits range from about $1.50 to $3.00 for every dollar invested, and when cities spent $15 to $65 annually per tree, net annual benefits ranged from $30 to $90 per tree (US EPA, 2014).

Richmond Tree Cost Calculations

At the implementation stage, at its most basic level, it would cost **$9,161,766.21** to plant trees over a 10-year period and **$15,257,426.04**, including management costs. However, the Benefit-Cost Ratio (BCR) for the City of Richmond Street Trees is **1.36**. For every dollar spent on trees annually, the City of Richmond would see **a 36 percent return on investment** after 10 years (*Tree Inventory, City of Richmond, Virginia, Public Works*, n.d.).[16]

16 These calculations were converted from 2010 to 2020 dollars. They included capital and labor costs from a tree inventory done in 2010.

Figure 3: Power Mapping Template (Peterson, n.d.)



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