The Research Bureau

ENVIRONMENTAL (IN)JUSTICE

An evaluation of climate impacts on Worcester neighborhoods

REPORT 23-13

November 2023

WORCESTER REGIONAL RESEARCH BUREAU, INC. • RESEARCH IN THE PUBLIC INTEREST • WRRB.ORG

EXECUTIVE SUMMARY

Creating cities that are fair and inclusive requires a deep understanding of how environmental factors impact communities. This report delves into the complex relationship between temperature, tree coverage, energy costs, and health outcomes. By examining these factors, we shed light on how vulnerable populations often bear the brunt of environmental harm. The report, accompanied by an interactive StoryMap, sheds light on the intersection of environmental concerns and social vulnerability. Below is an overview of the report's structure:

PAGES 3-6 | DISCUSSES THE CONCEPT OF ENVIRONMENTAL JUSTICE

- The U.S. Environmental Protection Agency (EPA) refers to Environmental Justice (EJ) as the principle in which every individual is equally and fairly treated regarding environmental legislation, regulation, policy formulation, implementation, and enforcement.
- In Worcester, some relevant research on these topics include a WPI's 2011 report that found higher concentrations of environmental hazards in lower-income and higher-minority neighborhoods, and 2022 research by a Clark University's Ph.D. student who analyzed the uneven distribution of high heat in Worcester, disproportionately affecting areas of higher social vulnerability and found a relationship between temperature and historical development in these areas.
- The Massachusetts Executive Office of Energy and Environmental Affairs (EEA) defines EJ Populations according to criteria on income, minority status, and English proficiency. In November 2022, the Massachusetts EJ maps were updated, from 2016-2020 sample data from the American Community Survey (ACS) to 2020 Decennial Census data. This update increased the EJ block groups at the state level from 2,316 to 2,604 of a total of 4,985, that is, an increase from 46% to 51% of the total. For Worcester, this increase was from 126 to 141, of a total of 171 block groups (from 74% to 83%).

PAGES 7-12 | REVIEWS WORCESTER ENVIRONMENTAL OUTCOMES' GEOGRAPHIC DISTRIBUTIONS

- According to data provided by the City of Worcester, collected between June 1st and August 31st, 2020, and using grid cells of 100 meters by 100 meters as the unit of analysis, for the 2020 summer, Worcester's average temperature ranged from 52.7°F to 83.0°F and the surface covered by trees ranged from almost 0% to 90%.
- At the census tract level, for 2020, the average annual energy cost per household ranged from approximately $1,000 to $3,000, while energy burden (the percentage of income used for energy) ranged between 2% and 4%.
- Some health variables that correlate with temperature and air quality across the city range as follows among adults: asthma, 10%-15%; high blood pressure, 25%-36%; fair or poor self-rated health status, 8%-30%; and lack of health insurance (18-64), 4%-22%.
- Except for high blood pressure, all the environmental, energy, and health variables analyzed in this report are unequally distributed geographically, disproportionately affecting neighborhoods with higher levels of vulnerability.

PAGES 12-14 | ANALYZES WORCESTER SITUATION AND ITS RELATIONSHIP WITH REDLINING

- The areas of the city classified as less desirable by Worcester's 1930s redlining map (made public by The Research Bureau in its 2022 report *Static Income, Rising Costs*) positively correlate with higher temperatures, lower tree cover, higher energy burden, asthma, worse self-rated health status, and lacking health insurance.

PAGES 14-17 | EXPLORES SIMILAR CITIES FROM AN ENVIRONMENTAL JUSTICE PERSPECTIVE

- Considering climate region and population, the cities compared to Worcester in this report are Rochester, NY; Providence, RI; and Yonkers, NY. The three exhibit an uneven distribution of variables like excessive heat and tree cover, affecting vulnerable communities disproportionately.

PAGE 18 | SUGGESTS WHAT CAN BE DONE

- In 2020, the City contracted with the Urban Climate Lab to conduct a heat risk assessment, which produced data provided to the Bureau for this report. Additionally, they modeled different heat management scenarios , including increasing the tree canopy and using cooling materials for paved surfaces and rooftops.

INTRODUCTION

Increasingly frequent climate events impact vast regions, underscoring the importance of understanding our natural and built environments. This report presents a comprehensive exploration of Worcester's environment, beginning with the origins of the Environmental Justice (EJ) movement from both social and theoretical perspectives. Then, it turns to cities akin to Worcester, briefly examining them through the lens of Environmental Justice. After providing this context, the report focuses on Worcester, systematically reviewing its environmental outcomes, spatial distribution, and correlation with social vulnerability. When possible, the disaggregation level of all variables will be Census Tracts, or higher granularity, to illuminate the differences among areas within the city. Finally, it intertwines these discoveries with redlining to explore if and to what extent it still shapes Worcester's present reality.

ENVIRONMENTAL JUSTICE

The United States Environmental Protection Agency (EPA) defines "Environmental Justice" as the principle in which every individual is equally and fairly treated regarding environmental legislation, regulation, policy formulation, implementation, and enforcement, regardless of race, color, national origin, or income. This entails that no individual shall endure a disproportionate part of the harmful environmental repercussions of industrial, governmental, or commercial activities and that everyone is entitled to equal access to decision-making about activities that may affect their environment and health (EPA 2023).

THE PIONEERING STUDIES

Environmental Justice as a movement began in the 1960s as part of the larger civil rights project by individuals, primarily people of color, who spoke out against the public health dangers of the disproportionate environmental repercussions they faced because of where they lived (EPA 2023).

According to EPA, the first-of-its-kind study analyzing the uneven distribution of environmental outcomes and its correlation with the socioeconomic and demographic profile of the affected communities in the United States was released in April 1983 by Dr. Robert Bullard, husband to Linda McKeever Bullard, the attorney who filed a class action lawsuit to block a landfill from being built within two miles of 6 schools in Houston, Texas, after a group of African American homeowners organized to stop it. In the report, *Solid Waste Sites and the Black Houston Community*, Bullard found that all five city-owned garbage dumps, 80 percent of city-owned garbage incinerators, and 75 percent of privately owned landfills were sited in black neighborhoods. However, African Americans comprised only 25 percent of the city's population.

Just two months later, in June 1983, the United States Government Accountability Office (previously known as the General Accounting Office), an independent, nonpartisan agency often referred to as the investigative arm and watchdog of Congress, released *Siting of Hazardous Waste Landfills and Their Correlation with Racial and Economic Status of Surrounding Communities* (GAO 1983), expanding the geographic scope of the analysis. This report assesses whether there was a link between the placement of four hazardous waste landfills across Alabama, North Carolina, and South Carolina and the racial and economic conditions of the communities around them. Utilizing 1980 Census data and examining the areas four miles from the waste sites, the report discovered a link between the placement of hazardous waste landfills and the racial and economic conditions of the surrounding communities. Three of the four communities were majority Black, and at least 26% of the population in all four locations had an income below the poverty line.

Over the years, more people started or joined local efforts for environmental justice. The third pivotal study from this decade, issued by a religious community, is just an example. In the late 1970s, a group of Warren, North Carolina residents, roughly 62% Black and experiencing high levels of poverty, protested the state designation of a landfill in their county to dispose of polychlorinated biphenyls (PCBs). After six weeks of protests, covered by the national media and more than 500 arrests (United Church of Christ 2022), the United Church of Christ's Commission for Racial Justice, led by the Rev. Benjamin Chavis, Jr., and Rev. Leon White, issued its 1987 report *Toxic Wastes and Race in the United States* (Commission for Racial Justice 1987), the first national report to comprehensively document and statistically prove the presence of hazardous wastes in racial and ethnic communities. With racial and socio-economic data from the 1980 U.S. Census and the EPA's Toxic Release Inventory (TRI), the report summarized two cross-sectional studies; one focused on commercial hazardous waste facilities, the other on uncontrolled toxic waste sites. The report concluded that (i) communities with a higher percentage of minority population were more likely to contain commercial hazardous waste facilities, (ii) there was an unusually high concentration of uncontrolled hazardous waste sites among Black and Hispanic populations, and (iii) race was a statistically significant factor in determining where these sites were located throughout the country.

ENVIRONMENTAL STUDIES ON WORCESTER

Since the release of these reports, dozens of other studies have examined how environmental outcomes are unequally distributed across the nation at the expense of poorer and more vulnerable communities. These studies are usually conducted for major cities and metro areas since temperature data, for example, tends to be available at a larger geographic scale. For this reason, the literature on these issues is not extensive for Worcester. Still, some of the city's higher education institutions have recently analyzed the relationship between environmental issues and demographics. Two are of particular interest to this report.

In 2011, Michael Bowen, Kathleen Hodge, David Ilacqua, and Margaret McDonough, all graduates of Worcester Polytechnic Institute (WPI), published the report *Environmental Injustice in Five Worcester Communities: The Role of Income, Race, and Education on Unequal Exposure to Environmental Hazards* (Bowen, et al. 2012). This study focused on five communities: Bell Hill, Main South, Piedmont, Oak Hill, and Quinsigamond Village, and included seven other comparison neighborhoods (Burncoat, Forest Grove, West Tatnuck, Newton Square, Hadwen Park, Grafton Hilland, and Green Island). The report studied the association between community demographics and the distribution of contaminants. Using demographic data from the 2010 Census, the researchers documented environmental hazards in the city over seven weeks based on EPA definitions. They followed the methodology of the 2005 study *Unequal Exposure to Ecological Hazards*, which investigated sixteen environmental hazards in over 350 Massachusetts municipalities in 2002 and 2005. The more than 1,000 environmental hazards in the city were categorized into land/waste, air, water, toxic/TURA (recognized as a toxic waste site by the Toxic Use Reduction Act), superfund landfills (municipal incinerators), and Massachusetts Department of Environmental Protection (DEP) Tier sites. The WPI report found higher concentrations of hazards in lower-income and higher-minority neighborhoods, particularly in the five communities under study, compared to other Worcester neighborhoods.

According to the article *Unequal Heat*, by the Woodwell Climate Research Center (Ruiz 2022), in 2022, a second-year Ph.D. student at Clark University, Arman Bajracharya, researched temperatures in Worcester. Using demographic data and satellite images, Bajracharya investigated the uneven distribution of high heat in Worcester, which disproportionately affected areas of higher social vulnerability. Additionally, Bajracharya found a relationship between temperature and historical development in these areas. An examination of land use (grass, water, tree cover, and residential imperviousness) showed that high tree cover and the consequentially lower land surface temperatures were correlated with communities with higher socioeconomic profiles. On the other hand, communities of color and low-income areas continue to be disproportionately exposed to risk, including lack of access to existing blue and green spaces.

OPERATIONALIZING ENVIRONMENTAL JUSTICE

> "The people shall have the right to clean air and water, freedom from excessive and unnecessary noise, and the natural, scenic, historic, and esthetic qualities of their environment; and the protection of the people in their right to the conservation, development and utilization of the agricultural, mineral, forest, water, air and other natural resources is hereby declared to be a public purpose."
>
> ***Constitution of the Commonwealth of Massachusetts, Article 97***

Massachusetts' current Environmental Justice Policy, initially issued in 2002, was updated on June 24, 2021. Based on the Constitution of the Commonwealth of Massachusetts, Article 97, and considering that Environmental Justice (EJ) is based on the principle *that all people have a right to be protected from environmental hazards and to live in and enjoy a clean and healthful environment regardless of race, color, national origin, income, or English language proficiency*, it is defined as *the equal protection and meaningful involvement of all people and communities with respect to the development, implementation, and enforcement of energy, climate change, and environmental laws, regulations, and policies and the equitable distribution of energy and environmental benefits and burdens*.

Like other social concepts, Environmental Justice demands comprehensive definitions that place it within a specific theoretical framework and provide the necessary nuances, like the one above, but also requires operationalization — in other words, spelling out precisely how the concept will be measured. To achieve this, the current Policy identifies an EJ Population as a neighborhood that the Executive Office of Energy and Environmental Affairs (EEA) has determined to be most at risk of being unaware of or unable to participate in environmental decision-making or to gain access to state environmental resources, or are especially vulnerable, meeting one or more of the following criteria:

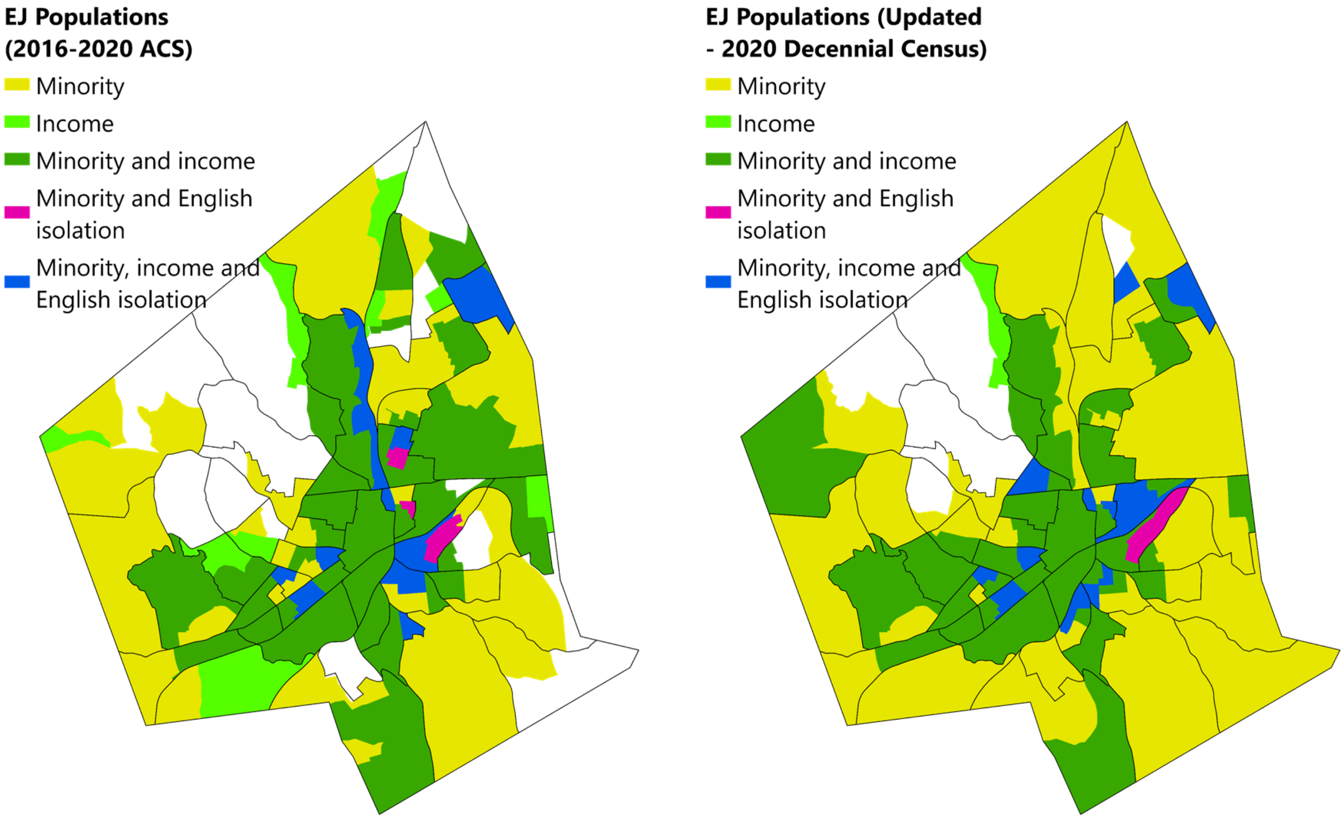
- The annual median household income is not more than 65% of the statewide
- 40% or more of the population is non-White
- 25% or more of households lack English language proficiency
- 25% or more of the population is non-White, and the annual median household income of the municipality in which the neighborhood is located does not exceed 150% of the statewide.

The current policy and the EEA's Act Creating a Next Generation Roadmap for MA Climate Policy (Session Laws. Acts 2021. Chapter 8) stipulate the creation of EJ maps that must be regularly updated as part of the services to be provided to EJ populations to enhance public participation and engagement. The EJ Map for Massachusetts used the 2020 American Community Survey (ACS) 5-Year Estimates, which aggregate data comprising the 2016-2020 period, until November 12, 2022, when it was updated to reflect the 2020 Decennial Census data (this release was delayed due to the Covid-19 pandemic).

Following this definition, Map 1 displays EJ populations according to the EEA, utilizing Census Block Groups as the unit of analysis. As can be seen, when comparing the situation before and after the 2022 update, i.e., comparing the 2016-2020 sample data against the 2020 census data, the city experimented a notable shift in designated EJ populations. Among its 171 block groups, those classified as EJ populations increased from 126 to 141. This accounts for an increase of nearly nine percentage points, rising from 73.7% to 82.5%.

Map 2, on the following page, shows these populations at the state level, showcasing a pattern of an increasing number of neighborhoods categorized as EJ Populations.

Map 1: Worcester Environmental Justice Map. Comparison of 2016-2020 ACS and 2020 census data

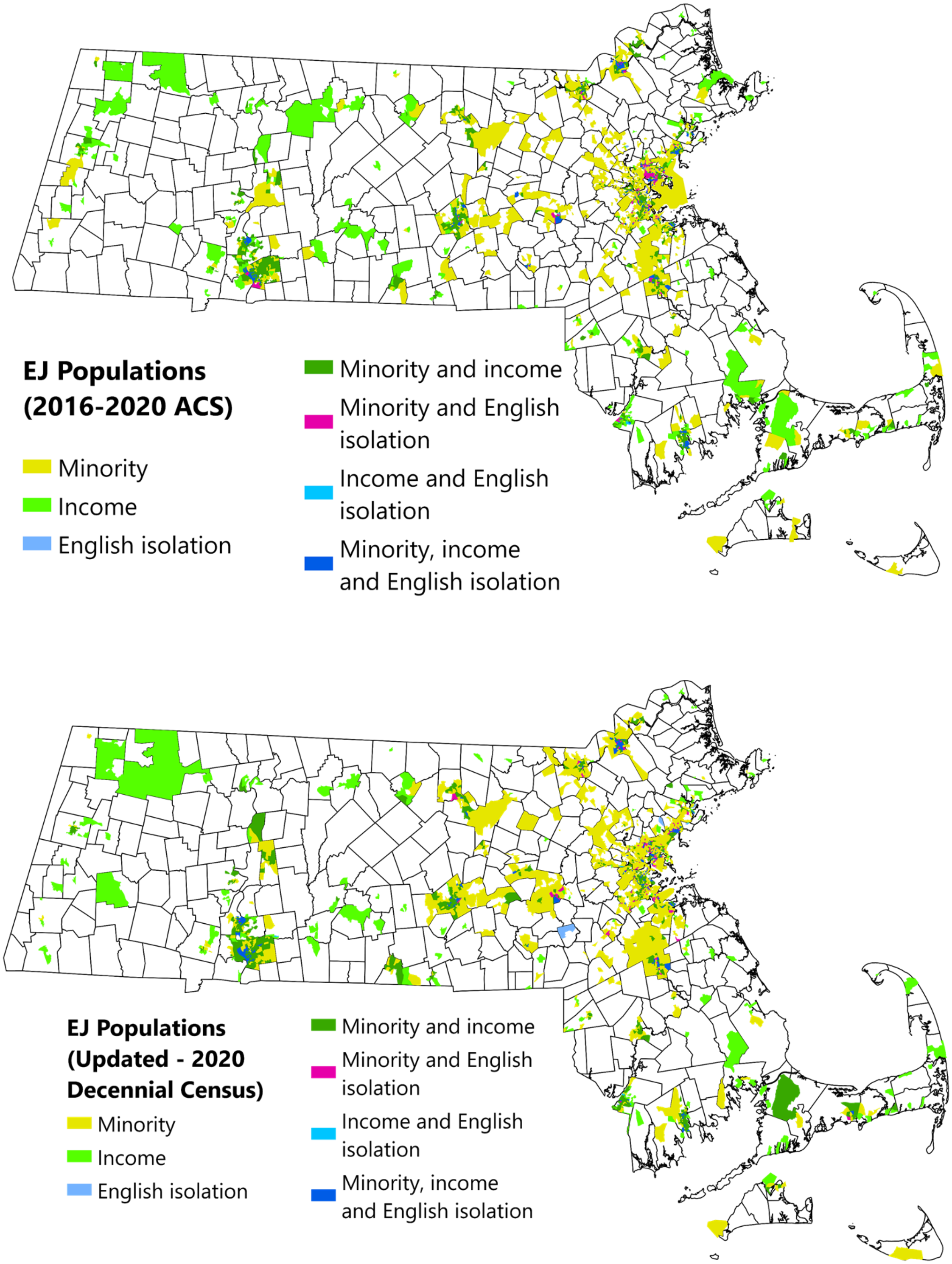


Source: Mass Gov website (link)

Following the 2022 update at the state level:

- The number of EJ block groups increased from 2,316 (46% of the total) to 2,604 (51% of the total) out of a total of 4,985 in Massachusetts
- The number of people living in EJ block groups increased from 3,100,468 to 3,487,681, or 12.5%
- The number of municipalities with EJ block groups decreased from 188 to 187

Map 2: Massachusetts Environmental Justice Map. Comparison of 2016-2020 ACS and 2020 census data



Source: Mass Gov website (link)

WORCESTER ENVIRONMENT

Building upon a similar approach as the studies above, this report delves deeper into the relationship between environmental outcomes and the affected communities in Worcester. The first step before comparing is to assess the environmental situation of the city.

TEMPERATURE AND TREE COVERAGE

A primary challenge in analyzing data like temperature is the availability of data at a relevant level of granularity. Temperature estimates often encompass extensive geographical areas, providing temperature values for entire cities or regions. Fortunately, there is recent data available in Worcester that is useful for in-depth analysis.

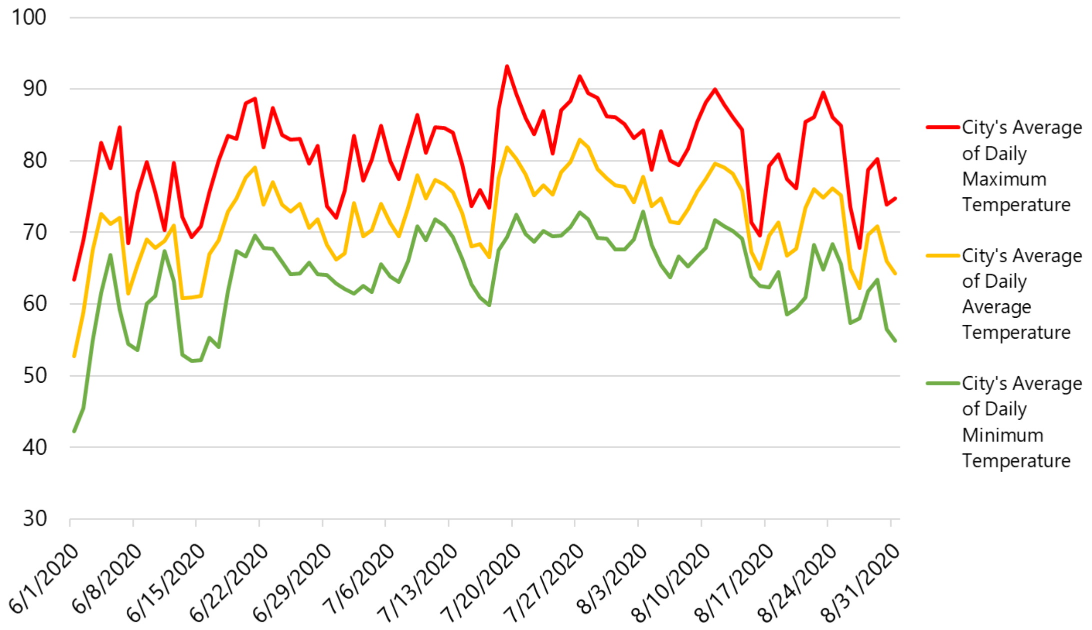
Given that excessive heat was identified as one of the three key climate change hazards in the 2019 Worcester Municipal Vulnerability Preparedness Plan, the City contracted with the Urban Climate Lab at the Georgia Institute of Technology to conduct a heat risk assessment. This assessment, presented to the City Manager and City Council in February 2023, included the dataset employed for this report. Throughout the summer of 2020 (from June 1st to August 31st), the Urban Climate Lab measured minimum, average, and maximum daily temperatures, utilizing grid cells measuring 100 meters by 100 meters, covering a total of 9,954 grid cells across the entire city. Since all grid cells had the same surface, calculating their general average is equivalent to the city's average. Chart 1 was created following this calculation. Both the minimum and maximum daily temperatures, as well as the average temperature, exhibited ranges of approximately 30°F during the summer of 2020 for the entire city.

- The **minimum** daily temperature ranged from 42.2°F on June 1st to 72.9°F on August 3rd.
- The **average** daily temperature ranged from 52.7°F on June 1st to 83.0°F on July 27th.
- The **maximum** daily temperature ranged from 63.4°F on June 1st to 93.2°F on July 19th.

However, as one might expect, the geographic distribution of these temperatures is not uniform. Following the logic of the Municipal Vulnerability Preparedness Plan, which identifies excessive heat as a significant concern, Map 3 illustrates the average maximum daily temperature between June 1st and August 31st, 2020 for each cell.

High temperatures are concentrated in specific regions of the city. To the north, they are centered around Greendale and Burncoat; to the west, around the Worcester Regional Airport; and in Worcester's center, the epicenter is in downtown, but high temperatures cover neighborhoods such as Union Hill, Vernon Hill, and Oak Hill, from where it extends along Shrewsbury Street and reaches the Biotech Research Park region.

Chart 1: City of Worcester daily temperatures during Summer 2020 (F°)



Source: Own elaboration based on the City of Worcester Heat Risk Assessment data

Within these regions, there are scattered cells where the average summer maximum daily temperature exceeded the 2020 summer city's average of 87°F, reaching maximum values of 96°F.

As expected, there is a close relationship between temperature and tree canopy in the city. While initiatives like the Worcester Tree Keeper aim to maintain an individualized inventory of trees in streets and parks, that is not the only effort about tree coverage in the city.

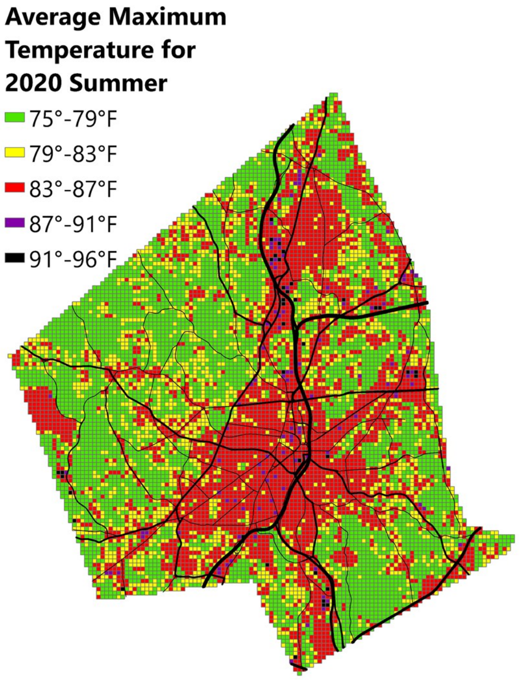
In April 2023, the City of Worcester released a draft Urban Forest Master Plan (UFMP) to guide the further preservation, management, and expansion of Worcester's public "street trees." The UFMP intends to guide long-term budgets and inform other management plans, transitioning from reactive to proactive management, not only engaging with resident concerns but anticipating them. The UFMP concept was first identified as part of the 2013 Open Space and Recreation Plan, and its development was further refined in the Green Worcester Plan released in 2020. The planning process began in late 2021 and the final version of the draft issued in early 2023 is still pending approval and release.

Another relevant effort on this topic is the Human-Environment Regional Observatory (HERO) program at Clark University, which focuses on researching human-environment relationships in Massachusetts and has been actively involved in examining tree health in the area affected by the 2008 Longhorned Beetle outbreak. In 2023, they conducted a study, building on previous surveys, to assess ecosystem outcomes, growth, and survivorship of trees planted between 2010 and 2012 by the Department of Conservation and Recreation and Worcester Tree Initiative following the outbreak. The study revealed that the survivorship rates for a sample of 2,794 trees (85% residential, 15% street), were 66.9% for private trees and 88.6% for street trees. Furthermore, the study estimated that the private trees in the sample contributed over $7,206 worth of ecosystem services, producing 12.2 pounds of oxygen, and sequestering 4.6 tons of carbon and 238 pounds of pollution in 2023.

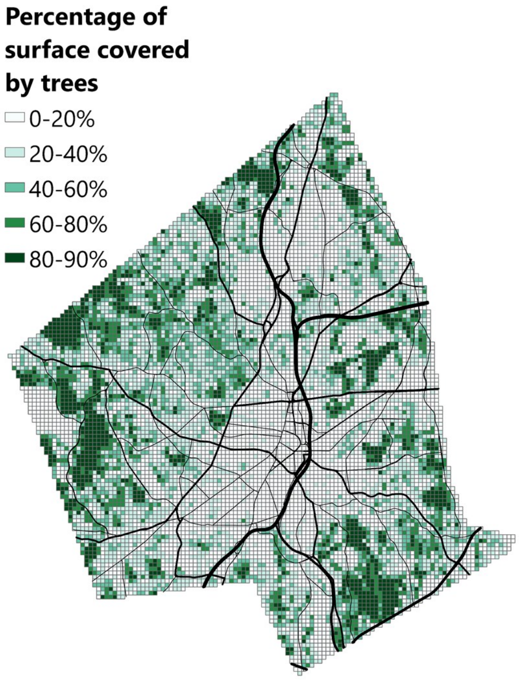
Similar to temperature, the dataset collected by the Urban Climate Lab and provided by the City for this report included a section that measures the percentage of surface covered by tree canopy for the entire city, utilizing as unit of analysis the same set of grid cells of 100 meters by 100 meters, including non-public parcels. Map 4 displays the geographical distribution of tree coverage.

Comparing the tree coverage maps with the maps of maximum daily temperature (both including the city's main streets) shows an inverse correlation between the two: regions with lower tree canopy cover also generally experienced higher average maximum daily temperatures during the summer of 2020.

Map 3: City of Worcester maximum daily temperatures during Summer 2020

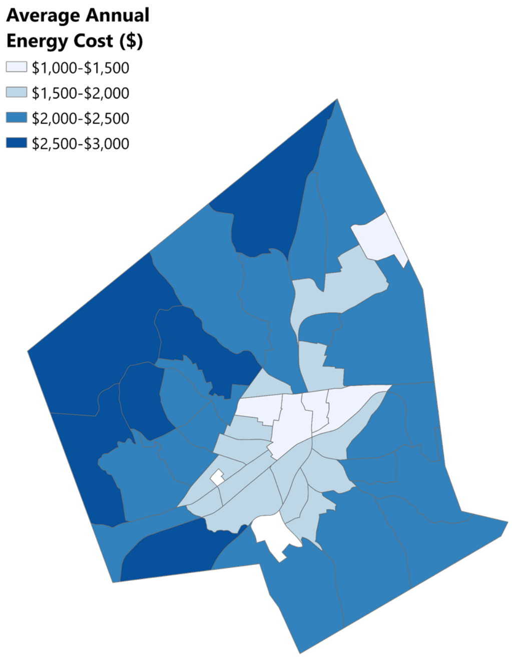


Map 4: City of Worcester Tree Cover Percentage

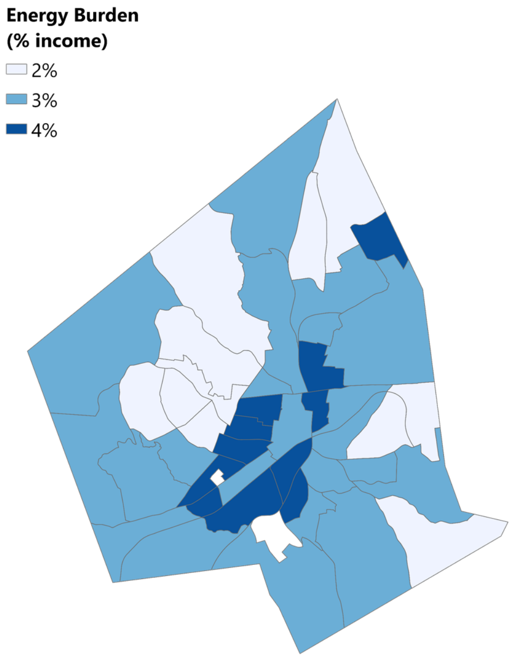


Source: Own elaboration based on Worcester City's Heat Risk Assessment data

Map 5: City of Worcester Energy Costs



Map 6: City of Worcester Energy Burden



Source: Own elaboration based on LEAD data

ENERGY COSTS

According to the United States Environmental Protection Agency (EPA), the national electrical grid is vulnerable to climate change, including rising temperatures, heat waves, cold and snow events, severe drought, intense rainfall, sea level rise, hurricanes, and wildfires. For the case of heat events, as the demand for cooling increases, more electricity must be produced to meet this demand. Like temperatures, the energy costs are not uniformly distributed, as lower-income communities carry a higher energy burden.

Nationally, low-income households spend 8.6% of their income on energy expenses, while non-low-income households spend 3%. Factors contributing to this burden include living without insulation or with outdated appliances and the barriers to accessing clean and more affordable technologies (EPA 2023).

The Low-Income Energy Affordability Data (LEAD) was utilized to analyze the distribution of energy costs in Worcester. The Federal Office of State and Community Energy Programs (SCEP) made this dataset available to the public. As part of the resources they have developed, the LEAD Tool provides information on average annual costs and energy burden (the percentage of household income used for energy) at the census tract level, enabling the creation of Maps 5 and 6.

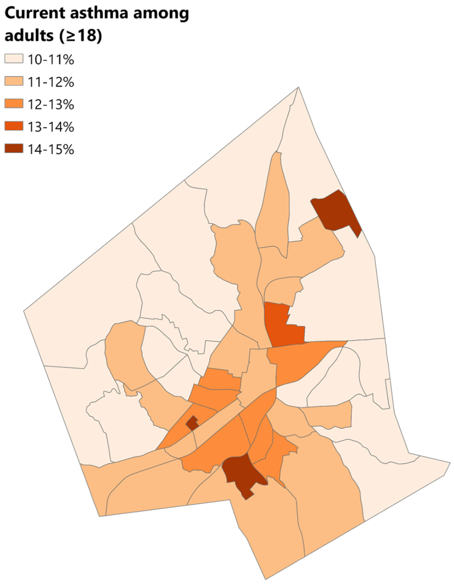
The maps show that average annual costs and energy burden are essentially inverse versions of each other. More affluent households have higher total costs, but these represent a smaller proportion of their incomes. On the other hand, financially disadvantaged families have lower average costs (which is compatible with smaller homes and lower consumption), but constitute a higher percentage of their already limited incomes.

EFFECTS ON HEALTH

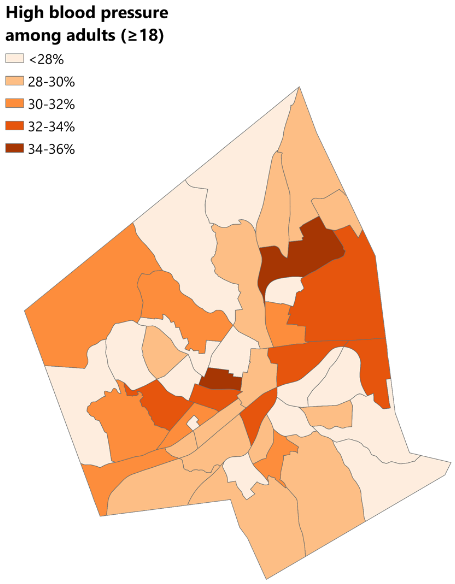
A crucial element in the analysis of environmental outcomes is their impact on health, as certain health conditions are closely related to climatic conditions, either because pollution may cause them (such as respiratory illnesses) or because factors like temperature exacerbate them (such as high blood pressure)—the 2022 release of the *PLACES: Local Data for Better Health* dataset was used for this analysis.

PLACES is an expansion of the original *500 Cities Project* that began in 2015 and was launched by the Centers for Disease Control and Prevention (CDC) in partnership with the Robert Wood Johnson Foundation (RWJF) and CDC Foundation. This source reports model-based, population-level analysis and community estimates of health measures, calculated by the Division of Population Health, Epidemiology, and Surveillance Branch at the CDC, and includes census tract data. The dataset reports health outcomes, preventive service use, chronic disease-related health risk behaviors, and health status measures.

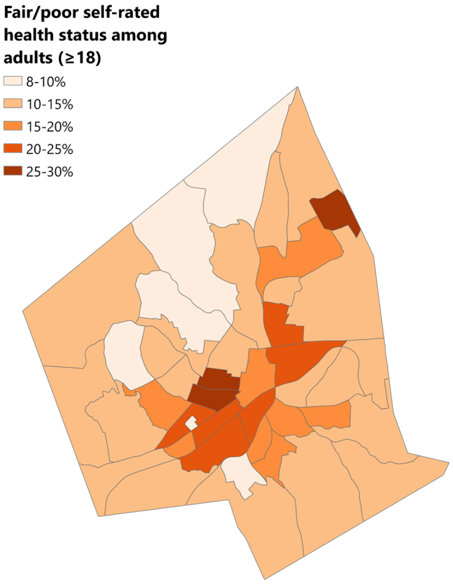
Map 7: Asthma



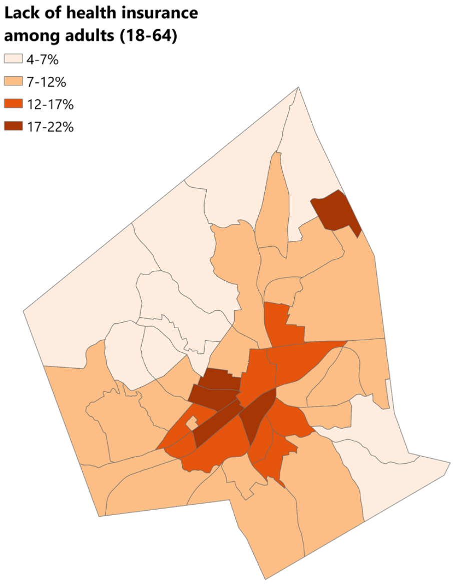
Map 8: High Blood Pressure



Map 9: Self rated health status



Map 10: Health Insurance



Source: Own elaboration based on PLACES data

Maps 7, 8, 9, and 10 show four of the measures calculated by the CDC in the PLACES dataset. The two health outcome variables (asthma and high blood pressure among adults) were selected for their relationship with air pollution and excessive heat. Additionally, lack of health insurance and fair-to-poor self-rated health status were included, the first as a measure of vulnerability to health issues and the second as an encompassing estimate of general health status.

While asthma, self-rated health status, and lack of insurance remain ordinally consistent (low and high values correspond to basically the same census tracts, regardless of specific scales), high blood pressure among adults seems more geographically widespread. It's worth noting how the three consistently ordered variables (asthma, self-rated health status, and lack of insurance) seem to replicate both the temperature map and the energy burden map and are the inverse of the tree coverage map.

ENVIRONMENTAL OUTCOMES AND SOCIAL VULNERABILITY

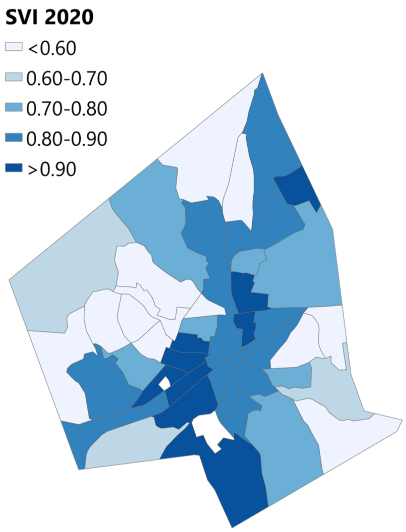
The next step in the analysis compares the spatial distributions of the variables above with the city's demography. However, rather than comparing them with specific demographic variables, such as poverty or race/ethnicity, like the reports discussed in the initial section, this report compares them with a more comprehensive index, the Social Vulnerability Index.

The CDC calculates the Social Vulnerability Index (SVI) using ACS data, and it is available at the census tract level. It comprises four thematic measures: Socioeconomic, Household Composition & Disability, Minority Status and Language, and Housing Type and Transportation. The index ranges from zero to one; the higher the index, the more vulnerable the census tract is.

Map 11 on the following page shows the geographic distribution of the 2020 SVI. Additionally, the scatterplots of Chart 2 compare this index with some of the previously discussed variables. Please note that the variable "tree coverage" (percentage of the surface covered by trees, ranging from 0 to 1) was inverted to become "lack of tree coverage" (1 - tree coverage). For example, if a census tract had a value of 0.25, it is now represented as 0.75.

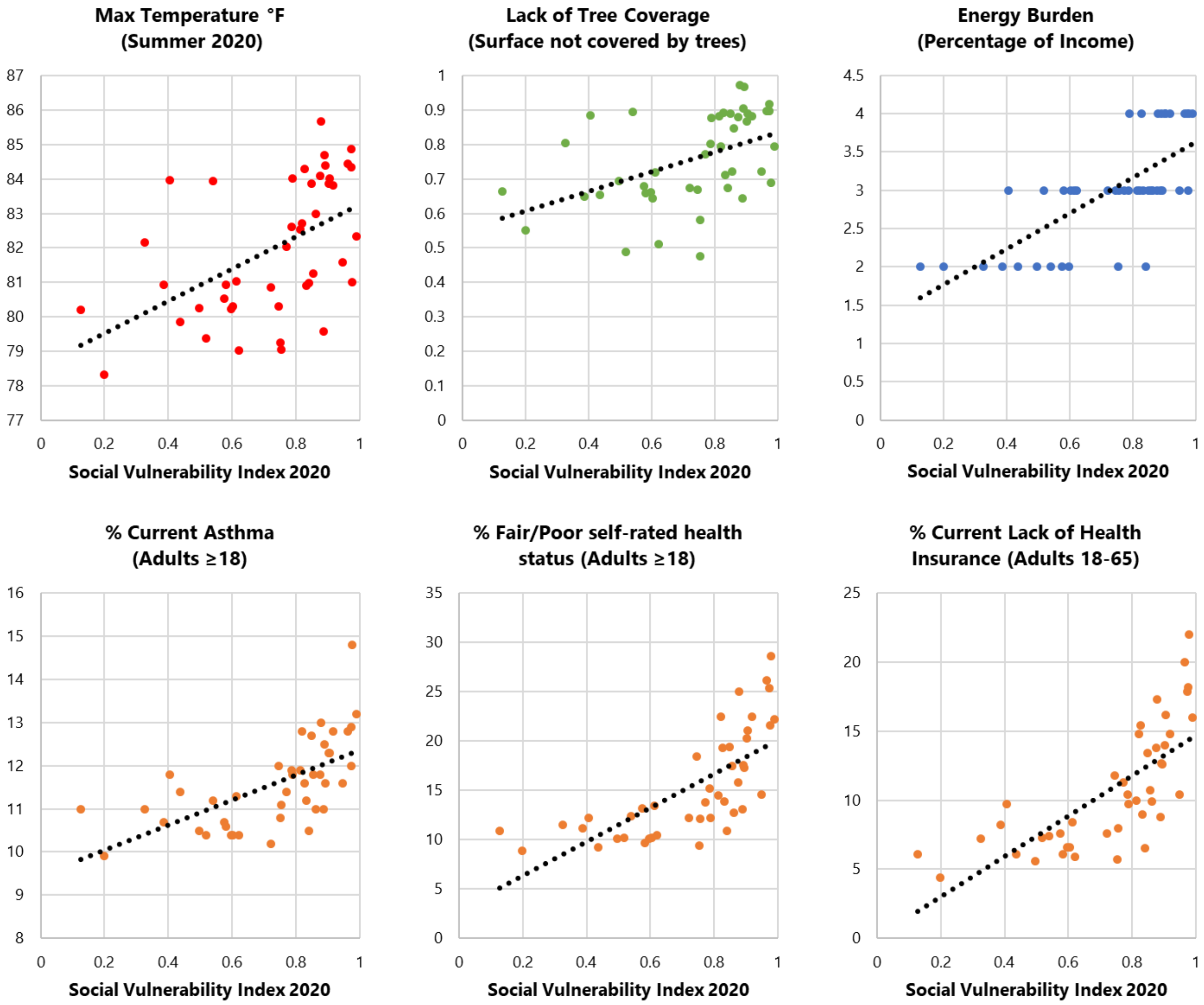
All the graphs have SVI on the horizontal axis and the corresponding variable on the vertical axis. Each point represents one of the 44 census tracts within the city. As can be seen, all of them have a positive correlation with the variables studied in this report, reflected on the dotted trendline of each graph. In other words, the more vulnerable a census tract is, its value is higher in terms of maximum daily temperature, lack of tree coverage, energy burden, and health issues. The level of inclination of each trendline represents how strong the positive correlation is; the steeper the slope, the stronger the positive correlation.

Map 11: Social Vulnerability Index (2020)



Source: Own elaboration based on CDC data

Chart 2: Correlations between Social Vulnerability and Environmental, Energy, and Health Measures



Source: Own elaboration based on CDC data, Worcester's Heat Risk Assessment data, LEAD data, and PLACES data

This approach of comparing environmental outcomes with the SVI confirms the relationship between environmental and social vulnerability more robustly. The SVI not only reflects the economic, racial, and ethnic profile of these populations but goes further by involving many more variables such as household composition, disability status, English proficiency, housing type, and means of transportation. Similarly to the studies conducted by scholars at WPI and Clark University, this report confirms that more socially vulnerable communities experience more adverse environmental consequences in the City of Worcester.

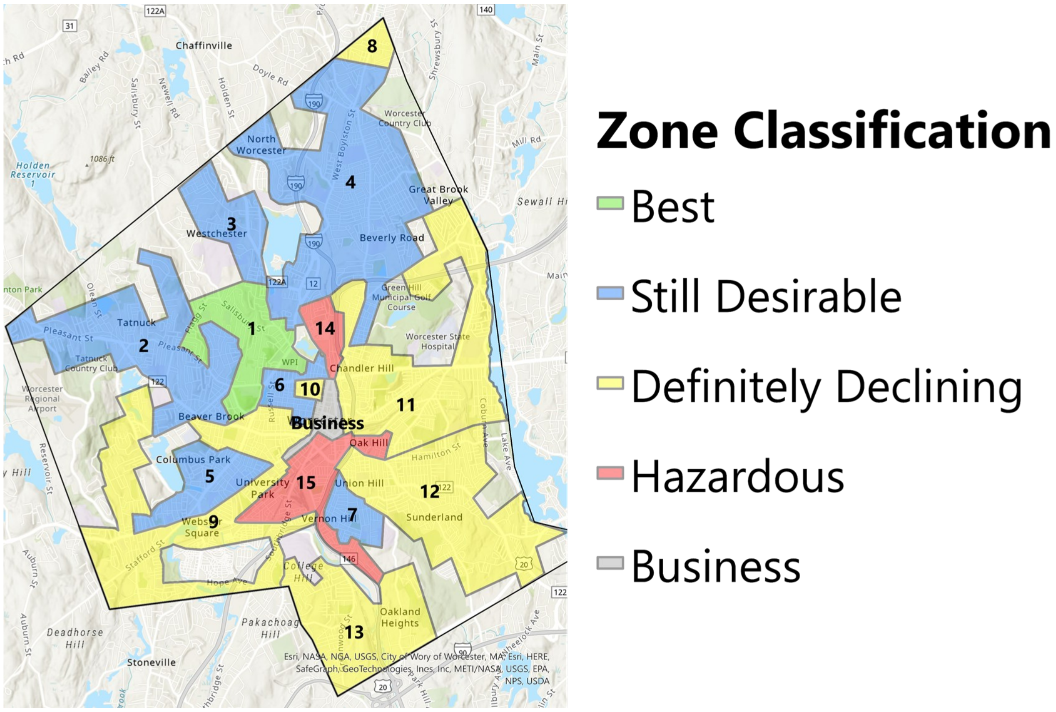
REDLINING AND ENVIRONMENTAL OUTCOMES

Climate and environmental patterns are complex and multifactorial phenomena. Historical developments from across the 20th century, including choices made about what to build and where may also affect who and how feels the effects of these patterns. One variable that may help us understand (though, of course, not fully explain) is redlining.

In the 1930s, the Federal Home Owners' Loan Corporation (HOLC) categorized neighborhoods in hundreds of cities in the US into four types: **Best** (A), **Still Desirable** (B), **Definitely Declining** (C), and **Hazardous** (D). So-called "hazardous" zones were colored red on these maps, hence the name "redlining." These zones were then used to approve or deny credit lending and mortgage-backing by banks and the Federal Housing Administration. The descriptions provided by HOLC in their reports rely heavily on income, race, and ethnicity as critical elements in assigning these grades. The redlining map for Worcester was digitized and made publicly available for the first time in decades by The Research Bureau in 2022, thanks to a photo snapped by scholars at the University of Richmond's Mapping Inequality project at the WRRB's request.

The Bureau already performed a geostatistical analysis with this map in its 2022 report Static Income, Rising Cost, in which a correlation between being redlined in the 1930s and current demographic and socioeconomic data was shown. The analysis used was geographic apportionment, in which regions originally defined by the redlining map were updated with current data based on overlapping census tracts. This process allows us to translate old geographies into current measures to answer the question of how those original regions would look like today with recent data. In other words, this allows us to investigate how areas in the city, which were historically deprived of economic development opportunities, connects with contemporary measures. Thus, we are able extract valuable insights into the enduring impact of past policy decisions on present-day outcomes

Map 12: Worcester 1936 Redlining Map



Source: WRRB's elaboration based on a photo provided by the University of Richmond's Mapping Inequality project

Chart 3 shows the original redlining map and the result of performing this process for six of the previously discussed variables: Summer 2020 maximum daily temperature, tree coverage, energy burden, current asthma, fair/poor self-rated health status, and current lack of insurance. As can be seen, the areas categorized as "declining" and "hazardous" almost 80 years ago are now experiencing higher daily maximum temperatures, lower tree coverage, higher energy burden, and poorer health indicators.

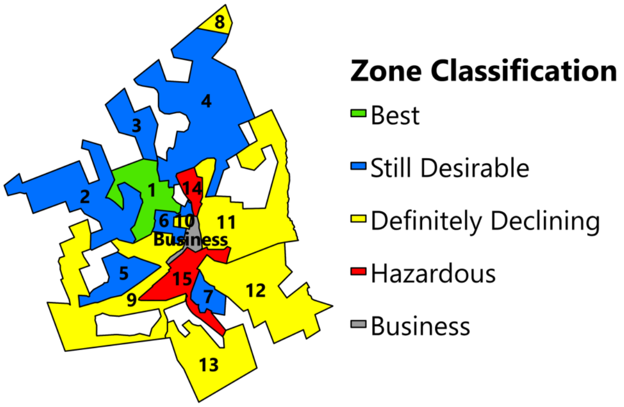
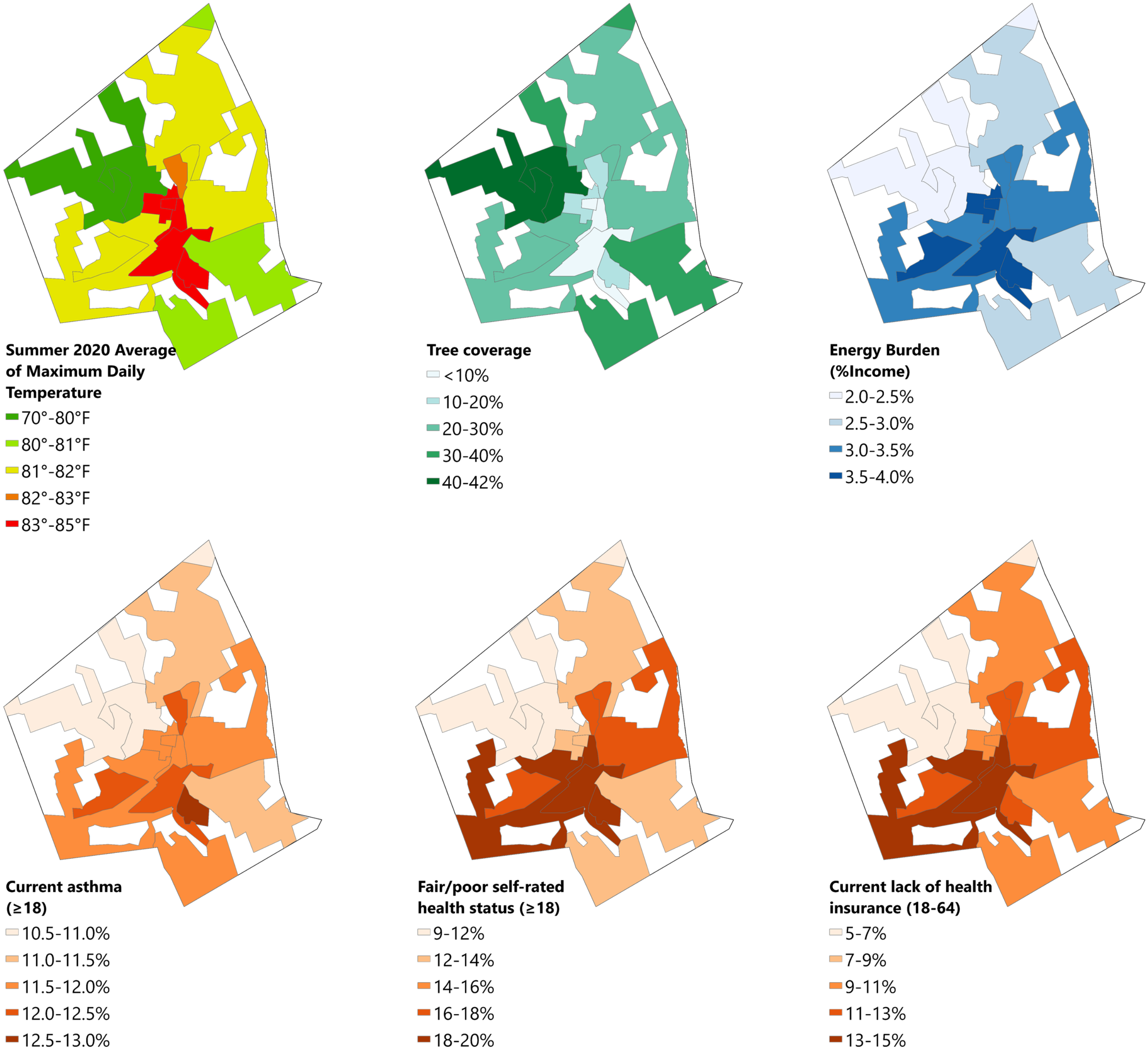


Chart 3: Environmental, Energy, and Health Measures Apportioned to 1936 Redlining Zones



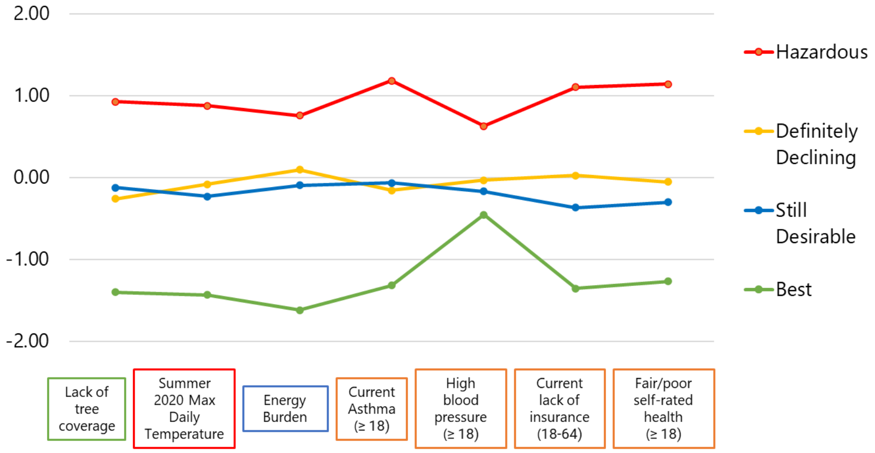
Source: Own elaboration based on CDC data, Worcester's Heat Risk Assessment data, LEAD data, and PLACES data

While the observations mentioned above are visible when comparing the maps visually, Chart 4 presents the results of a more rigorous process. Since the variables are all distinct and measured in different units, The Research Bureau standardized the values for each variable to make them comparable. Standardization is a statistical procedure that rescales a variable to have an average of 0 and a standard deviation of 1 (unit variance). To see a more detailed explanation, go to Appendix 1.

As a final step, these standardized values were averaged based on the classification of zones in the 1936 redlining map: **Best** (Zone 1), **Still Desirable** (Zones 2, 3, 4, 5, 6, 7), **Definitely Declining** (Zones 8, 9, 10, 11, 12, 13), and **Hazardous** (Zones 14 and 15). The results of averaging the standardized scores by zone classification are presented in Chart 4. Note that the *business* zone, which corresponds to downtown, was omitted from the analysis because it is an outlier since high-income residents live there, but the population and business density explain higher temperatures, lower tree coverages, etc.

As can be seen, there is a clear pattern for all variables: the zones classified as Hazardous in the 1930s consistently performed worse in all indicators, in contrast to the Best-classified zone. On the other hand, the other two classifications are pretty close to the average of each variable. It is worth noting the particular case of blood pressure, where all classifications converge around the mean. This is consistent with what was mentioned in the health outcomes section, where Map 8 showed that this was the only variable that did not replicate the geographical patterns of the others.

Chart 4: Environmental, Energy, and Health Standardized Scores, Averaged by Redlining Zone Classification



Source: Own elaboration based on CDC data, Worcester's Heat Risk Assessment data, LEAD data, and PLACES data

ENVIRONMENTAL JUSTICE IN SIMILAR CITIES

As the United Church of Christ's Commission for Racial Justice pointed out in its 1987 report, environmental injustice is not an isolated phenomenon but rather a structural and nationwide one. After analyzing Worcester, contextualizing the analysis by comparing similar cities can put environmental injustice in Worcester into perspective. This section provides brief overviews of three cities that were considered comparable to Worcester.

The initial criterion identified cities within the same climate region as Worcester. These cities were found using the climate regions as defined by the National Centers for Environmental Information (NCEI) at the National Oceanic and Atmospheric Administration (NOAA), which has delineated nine climatically consistent regions within the contiguous United States, using monthly, seasonal, and annual temperatures between 1895 and 1983 (NCEI-NOAA n.d.).

Massachusetts, along with Connecticut, Delaware, Maine, Maryland, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont, belong to the Northeast Climate Region.

Next, cities with similar populations and population density within the Northeast Climate Region were sought out. Considering Worcester's population of over 200,000 and its 5,512 people per square mile density, Rochester, NY, Providence, RI, and Yonkers, NY, fit these criteria. In addition, these cities also have another feature in common with Worcester: the existence of Redlining Maps. The following pages briefly overview these cities and the unequal distribution of environmental outcomes within them.

ROCHESTER, NY

- Population: 211,321
- Density: 5,870 people/sq mile
- Redlining map: available through the University of Richmond

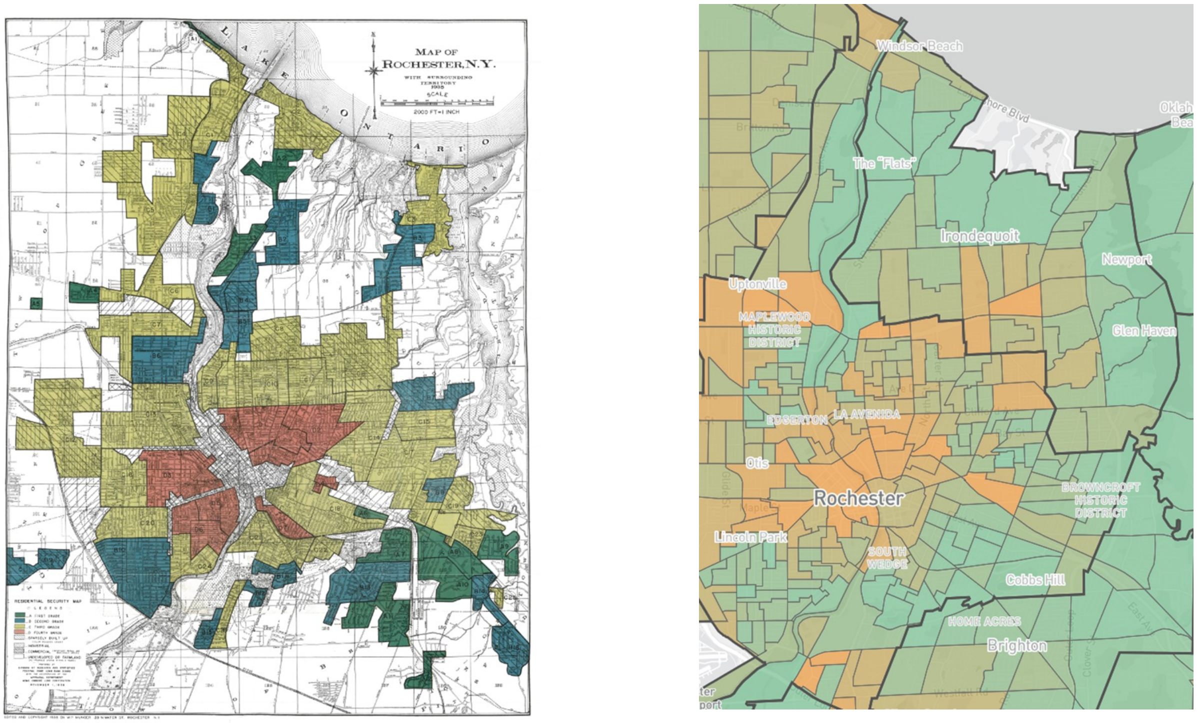
The city of Rochester is located in the Finger Lakes region of New York, and it is the third largest city in the state. Rochester is home to multiple colleges and many businesses, with an economy fueled mainly by technology and research (Office of Energy & Sustainability, City of Rochester 2018).

Rochester's average temperature in June 2020 was 75.6 degrees Fahrenheit, a departure from the normal average temperature of 70.7 from 1981-2010 (NCEI-NOAA 2023). It is projected that Rochester's average temperature will be up by 7 degrees Fahrenheit above its previous average by the middle of the century. Considering this, among many other issues, the state of New York has cited many census tracts in Rochester as Potential Environmental Justice Areas, as shown in Map X. Map Y shows a relationship between the city's redlining map and the temperature distribution.

According to 2022 research by Justin Murphy, the temperatures felt within the city on a given day can vary by around 12 degrees depending on location and factors like tree coverage. Neighborhoods with higher levels of tree cover, such as Highland Park or Cobbs Hill, are significantly cooler than neighborhoods with little tree cover, such as Upper Falls. A lack of trees often comes with higher temperatures, making neighborhoods in the Northeastern section of the city unbearably hot during the summer. These neighborhoods also show some of the city's highest rates of asthma and poor health.

In Rochester, more trees are being taken down than planted (From 2015 to 2021, 4,400 were planted, but 5,400 were removed), creating even wider differences in tree cover. In areas like its northeastern neighborhoods, fewer trees are planted, thus creating less shade and limiting their cooling properties. This area also has a higher proportion of renters, which adds to the tree coverage disparity because renters usually cannot plant their own trees. Additionally, in some areas of the city, there is resistance to planting, rooted in residents not trusting that the city will care for the trees as promised, citing upkeep issues such as broken branches and leaf piles.

Image 1: Rochester, NY, Redlining Map and Tree Equity Score



Source: Mapping Inequality, University of Richmond (link)

Source: Tree Equity Score (link)

PROVIDENCE, RI

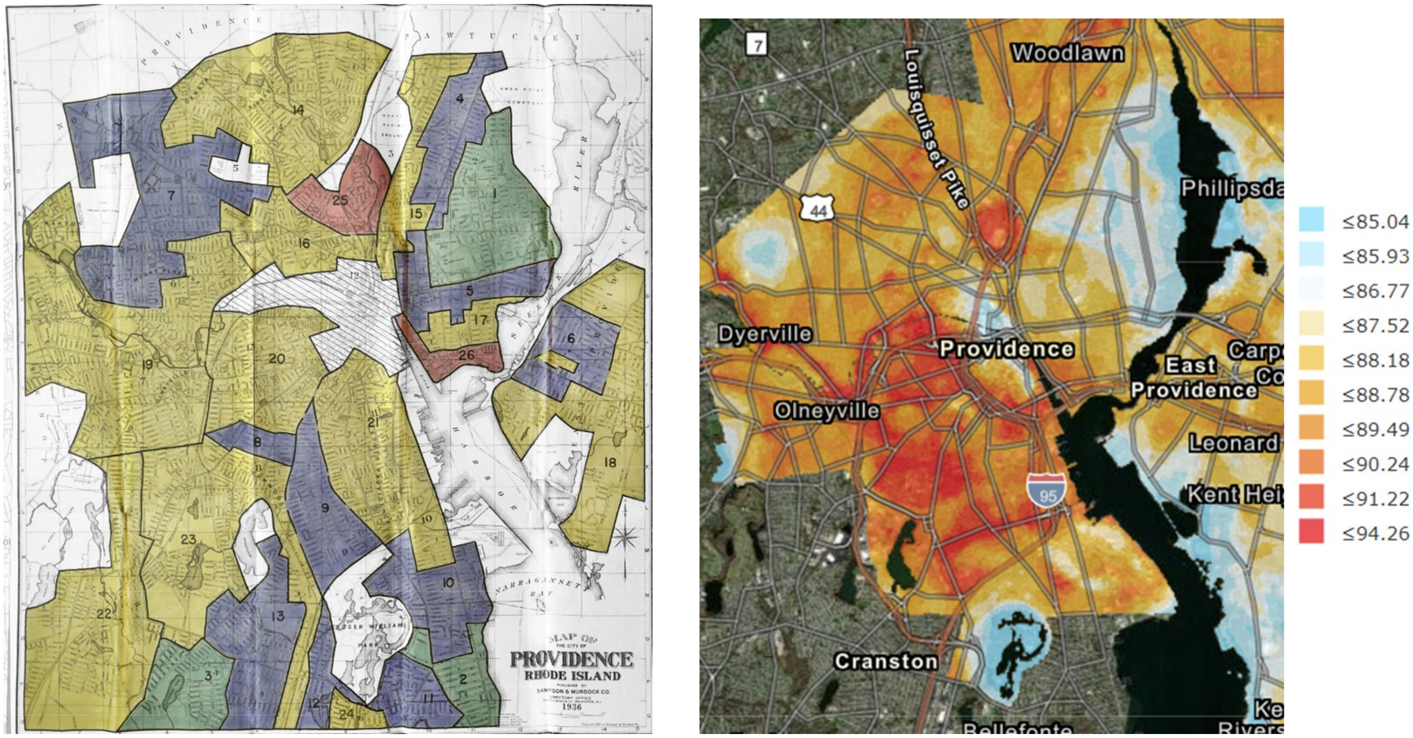
- Population: 190,932
- Density: 10,626 people/sq mile
- Redlining map: available through the University of Richmond

Providence is the capital of Rhode Island, the State's largest urban area, and the third-largest city in New England. Rhode Island is notable for having a wide range of daily temperatures throughout the year. The coastal nature of much of the state also creates variety in temperature, with the coastal region tending to be more temperate than the inland areas of the state. However, its relatively temperate climate is changing.

According to the Providence Journal (Perry 2020), 2020 was said to be one of the hottest years ever in Providence, with previously temperate and cool temperatures soaring. The average temperature in July was 77.6 degrees Fahrenheit, an increase from the 1981-2010 averages of 73.2 degrees Fahrenheit (NCEI-NOAA 2023). Throughout the summer of 2020, Providence experienced 23 uncharacteristically warm days with over 90 degrees Fahrenheit; the average number of summer days with temperatures over 90 is just 10 (Perry 2020).

Like the other cities studied in this piece, rising temperatures in Providence are not felt equally by all residents. Neighborhoods with poor tree cover are hotter than their shaded counterparts, with some areas experiencing over 10 degrees of difference (CAPA Strategies 2020). Indeed, the areas with the lowest tree equity scores had the highest surface temperatures and the highest numbers of people living in poverty. For example, neighborhoods in the city's northern section have over 80% of citizens living in poverty and multiple blocks with a tree canopy cover of under 20% of the surface. Additionally, neighborhoods near polluting industries and highways in Providence have the highest rates of poverty and non-white population. These same low-income communities of color have the state's highest asthma and lead poisoning rates. According to the 2019 Climate Justice Plan (City of Providence 2019), health outcomes for people of color in Providence are lower when compared to white people. Additionally, Providence faces similar tree removal problems as Rochester, as landlords and residents are removing many trees due to maintenance issues.

Image 2: Providence, RI, Redlining Map and CAPA Strategies Afternoon Temperature Model (July 29-30, 2020)



Source: Mapping Inequality, University of Richmond (link)

Source: CAPA Strategies, Heat Watch Rode Island (link)

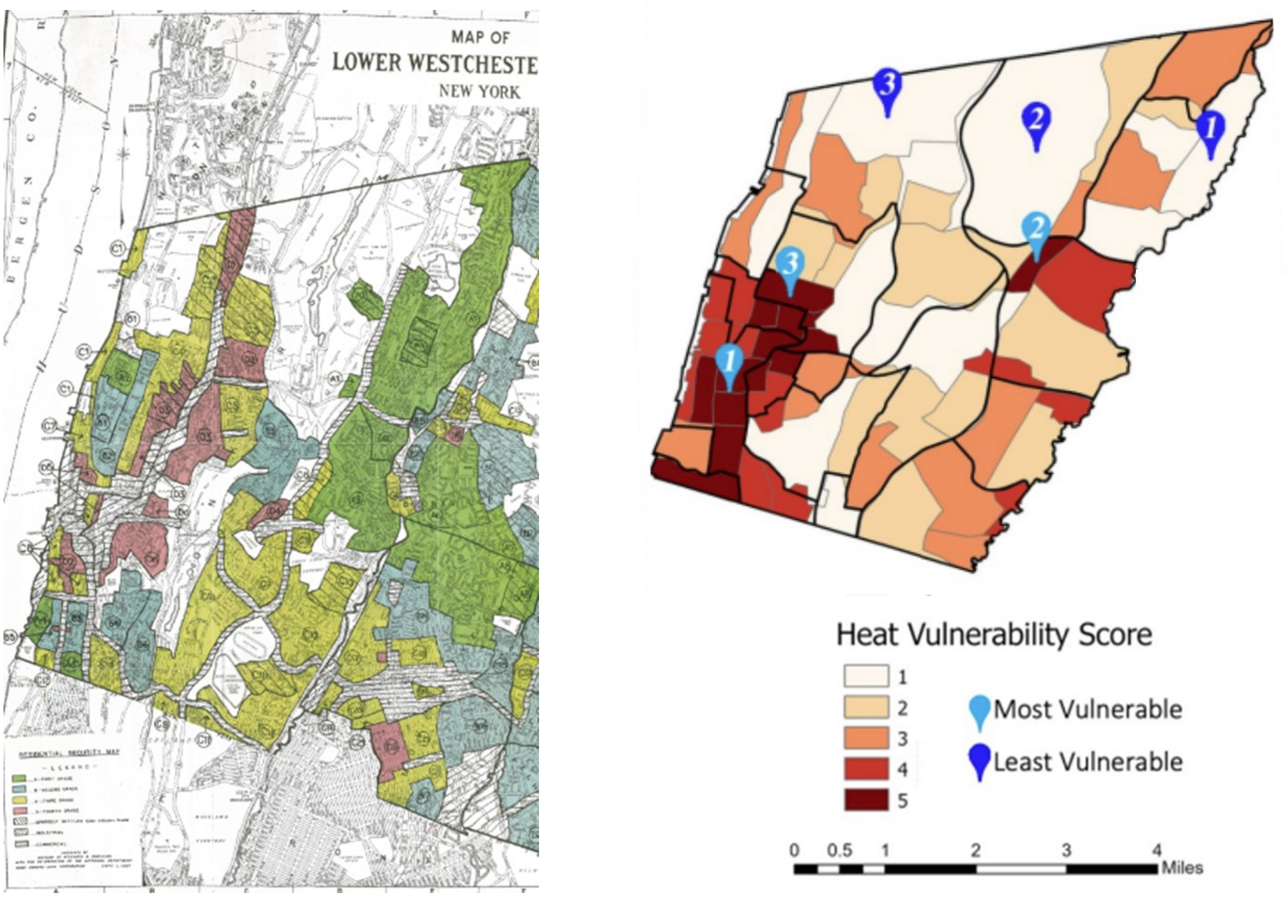
YONKERS, NY

- Population: 211, 585
- Density: 10,880 people/sq mile
- Redlining map: available through the University of Richmond

Yonkers is situated outside New York City, in Westchester County, and it’s the state’s fourth largest urban area. According to research done by NASA's Applied Earth Sciences Program (NASA DEVELOP 2021) and the ArcGIS StoryMap they developed following this report, many neighborhoods in Yonkers experience heat differently. This research has shown that the southwestern part of the city is the most vulnerable to heat and often was higher in temperature than the neighborhoods to the north and east. The parts of the city with the highest temperatures also have the fewest trees, with some areas having as low as 0.04% tree cover. Areas with the smallest tree cover also have the largest percentage of impervious surface coverage, such as concrete or asphalt.

Heat vulnerability, as in the other cities in this report, is also related to socioeconomic factors. Research done in Yonkers through NASA Develop notes that age, isolation, housing density, disability, employment status, race, income, and ability to speak English all play a role in heat vulnerability. For example, the Old 7th Ward neighborhood in southwest Yonkers ranks highly in heat vulnerability due to socioeconomic and surface temperature-related characteristics. This neighborhood has high rates of economic disadvantage, non-white residents, housing density, and temperatures.

Image 3: Yonkers, NY, Redlining Map and Heat Vulnerability Score (2021)



Source: Mapping Inequality, University of Richmond (link)

Source: Yonkers Urban Development II, Technical Report (Barbakova, 2021, link)

WHAT CAN BE DONE?

As shown in the previous section, similar cities also struggle with climate issues and their disproportionate geographic distribution. Nevertheless, the specific conditions of each city impacts which choices they make to mitigate these issues; so any recommendations on these topics must be tailored to those conditions.

Fortunately, the previously mentioned heat risk assessment conducted by the Urban Climate Lab at the Georgia Institute of Technology, contracted by the City, included the analysis of different approaches to mitigate heat risk.

The heat management scenarios were simulated and modeled based on the actual data collected to establish the "Base Case," which corresponds to the data presented in the second section of this report, to estimate their impact on heat reduction.

- **Tree Loss: Reduction in base case tree canopy of 10% for all census tracts**. Simulating a uniform loss of 10% canopy per grid cell results in a consistent but modest warming effect across the city.
- **Cool Materials (Albedo), rooftops, and surface paving**. An increase in the reflectivity of paved surfaces and rooftops has the general effect of increasing air temperature where the tree canopy is extensive, and reducing temperatures where the canopy is sparse or the parking surface is extensive, with an overall trend toward more warming than cooling.
- **Moderate Street Trees: All streets ≥15% canopy coverage**. Most effective in reducing temperatures along large roadways and high-density zones.
- **High Street Trees: All streets ≥25% canopy coverage**. This yields more significant cooling in high -density zones across the city.
- **Moderate Greening: Tree canopy ≥25% for all census tracts**. The difference between this one and the previous scenarios is that it is not restricted to street trees but the entire census tract surface. It substantially reduces air temperatures in the hottest zones of the city.
- **High Greening: Tree canopy ≥50% for all census tracts**. It largely mitigates the city's urban heat island and yields cooling up to 10 °F.
- **Combined**: Combination of Cool Materials and High Greening scenarios. It generally lowers temperatures in the urban center and elevates temperatures in heavily canopied tracts.

The general approach of the assessment evaluated exposure (estimates of the actual temperature and the modeling of the previously mentioned scenarios), sensitivity (estimates of heat-related mortality), and adaptive capacity (based on AC prevalence) at the census tract level in the city. These elements were combined to calculate Heat Vulnerability at the census tract level.

After considering the scenarios plus the heat vulnerability index, the Urban Climate Lab lists the following recommendations:

- An increase of total tree canopy across the city by 30,000 – 35,000 trees
- Not pursuing cool materials strategies without further analysis
- Assessing the number and siting of cooling centers for extreme heat events
- Establishing a citywide heat surveillance system with a density of at least five weather stations per census tract

CONCLUSION

Many cities worldwide and in the United States are devoting increasing resources and efforts to handle the several consequences of climate issues. An example of existing federal funding opportunities to mitigate the effects that infrastructure developments have not only on the social fabric and communities' interconnections but also on environmental outcomes is the Reconnecting Communities and Neighborhoods grant that the Massachusetts Department of Transportation, the City of Worcester and the Central Massachusetts Regional Planning Commission have applied for to study reestablishing connections across I-290 between the Vernon Hill and the Canal District and Green Island neighborhoods. At the state and local levels, the scenario is similar. The state-wide Municipal Vulnerability Preparedness (MVP) program is a clear example of this, as it provides support for cities and towns in Massachusetts to begin the process of planning for climate change resiliency and implementing priority projects, awarding communities with funding to complete vulnerability assessments and develop action-oriented resiliency plans, which makes them eligible for MVP Action Grant funding.

At the city level, the previously mentioned documents like the draft Urban Forest Master Plan or the Green Worcester Plan are examples of local efforts to react to and anticipate the upcoming challenges the city will experience in the forthcoming years. Nevertheless, due to the complexities involved in these topics, other issues, such as flooding risk areas or the environmental impacts of new developments on micro-regions of the city, justify further studies and analyses.

It is important to note that any action towards alleviating these issues, either the ones already considered by the City following the Urban Climate Lab recommendations or any suggested by local research, must be executed through the Environmental Justice lens.

The concept of Environmental Justice Populations used at the state level rightly serves as a guiding principle for environmental policies, recognizing communities susceptible to adverse environmental impacts and the structural barriers that may prevent them from effectively pursuing favorable changes in their favor. However, it's imperative to acknowledge the existence of other pertinent data, like the one presented in this report, that can further enrich our understanding. Incorporating these datasets into decision-making is crucial in fostering comprehensive efforts to address climate change, pollution, and tree coverage deficiencies and disparities.

The analyses presented in this report serve a dual purpose. First, they aim to enlighten the general public and decision-makers, ensuring that actions and interventions are rooted in robust data. Second, they provide valuable insights to professionals and organizations in specific sectors like public health, energy, economics, and forestry, underlining the intricate interconnection between environmental issues and their specialized domains.

The potential links between historical redlining and the studied variables extend our understanding of unevenly distributed environmental hazards and some of their causes. These findings highlight the persistent impact of historical decisions on contemporary communities. The resonance of these effects across various dimensions of vulnerability, as revealed by the Social Vulnerability Index, reinforces the urgency of addressing not only climatic implications but also broader socio-economic, linguistic, housing, and accessibility challenges.

APPENDIX 1

Standardization of a variable

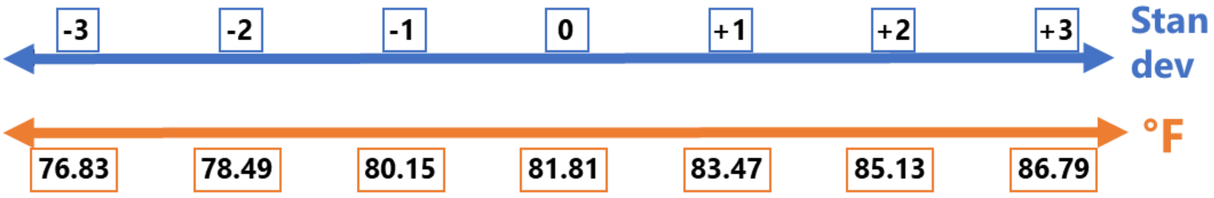
Standardization is a statistical procedure that rescales a variable to have an average of 0 and a standard deviation of 1 (unit variance). It's used to make comparable variables that have different units of analysis, as what is compared is relative location of each value with respect to its own average value.

As an example, let's consider the values of maximum daily temperature during the summer of 2020 shown in Map 4. The 16 zones from the redlining map have the values shown in Table 1. Standardizing a dataset requires subtracting the mean from each individual value and then dividing it by the standard deviation, as indicated in the table. With this process, each value is no longer expressed in °F but in *standard deviations*, showing how far it *deviates* from the mean. The mean will now take the value of 0 (the origin). When standardized, any value below the mean becomes negative, and those above it become positive. In variables that follow a normal or Gaussian distribution, 99.72% of the data falls between -3 and 3 standard deviations. Both Table 1 and Image 4 show the translation from °F to Standard Scores (Z).

Table 1: Example of the calculation of standard scores

Zone Number	Summer 2020 Max Daily Temperature		Standardized Score (Z)
1	79.42		-1.44
2	79.39		-1.45
3	79.25	$\mu = 81.81$	-1.54
4	81.58		-0.13
5	81.38	$\sigma = 1.66$	-0.26
6	83.77		1.19
7	83.14	$Z = \frac{x - \mu}{\sigma}$	0.81
8	80.95		-0.51
9	81.63		-0.10
10	84.12		1.39
11	81.66		-0.09
12	80.85		-0.58
13	80.81		-0.60
14	82.48		0.41
15	84.05		1.35
Business	84.39		1.55

Image 4: Translation from °F to Standard Scores (Z)



Source: Own calculations based on Worcester's Heat Risk Assessment data

BIBLIOGRAPHY

Bowen, Michael, Kathleen Hodge, David Ilacqua, and Margaret McDonough. 2012. "Environmental Injustice in Five Worcester Communities: The Role of Income, Race, and Education on Unequal Exposure to Environmental Hazards." WPI. December. https://digital.wpi.edu/pdfviewer/pz50gw51d

Bullard, Robert D. 1983. "Solid Waste Sites and the Black Houston Community." Sociological Inquiry. Spring. https://drrobertbullard.com/wp-content/uploads/2014/07/Bullard-Solid-Waste-and-Houston-Black-Community_Sociological-Inquiry-Vol-53-Spring-1983_4-7-14.pdf

CAPA Strategies. 2020. "Heat Watch Rhode Island." October. https://osf.io/jr9b7?view_only=1b5c811777f546bdb808088bfa24735b

City of Providence. 2019. "The City of Providence's Climate Justice Plan." https://www.providenceri.gov/wp-content/uploads/2019/10/Climate-Justice-Plan-Report-FINAL-English-1.pdf

Commission for Racial Justice. 1987. "Toxic Wastes and Race in the United States." United Church of Christ. https://new.uccfiles.com/pdf/ToxicWastes&Race.pdf

EPA. 2023. "Climate Change Impacts on Energy." United States Environmental Protection Agency. May. https://www.epa.gov/climateimpacts/climate-change-impacts-energy

EPA. 2023. "How Did the Environmental Justice Movement Arise?" United States Environmental Protection Agency. Accessed July 2023. https://www.epa.gov/environmentaljustice

EPA. 2023. "Learn About Environmental Justice." United States Environmental Protection Agency. Accessed July 2023. https://www.epa.gov/environmentaljustice/learn-about-environmental-justice

GAO. 1983. "Siting of Hazardous Waste Landfills and their Correlation with Racial and Economic Status of Surrounding Communities." U.S. Government Accountability Office. June 1. https://www.gao.gov/assets/rced-83-168.pdf

Murphy, Justin. 2022. "Rochester's trees are celebrated, but not everyone gets to have their time in the shade." Democrat and Chronicle. April. https://www.democratandchronicle.com/in-depth/news/2022/04/05/rochester-urban-tree-canopy-reflects-deep-racial-and-social-divisions/9357541002/

NASA DEVELOP. 2021. "Feeling the Heat in Yonkers. Understanding how people experience heat and a look at a cool future." October. https://storymaps.arcgis.com/stories/0f1414e41b2f4eca84d39ec7c5723630

NASA DEVELOP. 2021. "Yonkers Urban Development II." November. https://ntrs.nasa.gov/api/citations/20220000550/downloads/2021Fall_AZ_YonkersUrbanII_TechPaper_FD-final.docx.pdf

NCEI-NOAA. 2023. Climate at a Glance: City Time Series. Accessed August 2023. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/city/time-series

NCEI-NOAA. n.d. "U.S. Climate Regions." National Centers for Environmental Information, at the National Oceanic and Atmosphere Administration. Accessed August 2023. https://www.ncei.noaa.gov/access/monitoring/reference-maps/us-climate-regions

Office of Energy & Sustainability, City of Rochester. 2018. "Climate Vulnerability Assessment Report." City of Rochester. https://www.cityofrochester.gov/CVA/

Perry, Jack. 2020. "2020 may be warmest on record for Providence." The Providence Journal. December. https://www.providencejournal.com/story/news/local/2020/12/30/year-2020-could-warmest-record-providence/4071729001/

Ruiz, Sarah. 2022. "Unequal heat: A visit to Worcester, Massachusetts in the heat of summer highlights the inequities of rising temperatures." Woodwell Climate Research Center. March. https://www.woodwellclimate.org/climate-change-urban-heat-risk-worcester/

United Church of Christ. 2022. "A Movement Is Born: Environmental Justice and the UCC." Accessed July 2023. https://www.ucc.org/what-we-do/justice-local-church-ministries/justice/faithful-action-ministries/environmental-justice/a_movement_is_born_environmental_justice_and_the_ucc/

WORCESTER REGIONAL RESEARCH BUREAU, INC.

Officers & Executive Committee

Chair of the Board:
Francis W. Madigan, III

Vice Chair:
Paul Kelly

Treasurer:
George W. Tetler III, Esq.

Clerk:
Demitrios M. Moschos, Esq.

Assistant Clerk:
Kathryn Crockett

Executive Committee Members:
Kola Akindele, JD
Abraham W. Haddad, D.M.D.
Deborah Penta
Todd Rodman, Esq.
Rita Smith
John J. Spillane, Esq.
Eric K. Torkornoo

Board of Directors

Michael P. Angelini, Esq.
Stephen Aryitey
Joyce Augustus
Janet Birbara
Celia J. Blue
Melanie Bonsu
Edward S. Borden
Roberta L. Brien
Greg Byrne
Scott E. Casper, Ph.D.
Christine Cassidy
Francesco C. Cesareo, Ph.D.
Mel Chacharone
Chris Coghlin
J. Christopher Collins, Esq.
Brooke Cooper
Joseph Corazzini
Michael Crawford
Ellen Cummings
Andrew Davis
Boubacar Diemé
Donald Doyle
Justin Dufresne, PE
Sandra L. Dunn
Patty Eppinger
John Erwin
Allen W. Fletcher
David Fort
Tim Garvin
J. Michael Grenon
Kurt Isaacson
Carolyn Jackson
Will Kelleher
Dennis F. Kerrigan
Stephen Knox
Karen M. Lafond, Esq.
David LaPointe
Cheryl Lapriore
Michael Lavoie
James Leary
Meghan Liddy
Karen E. Ludington, Esq.
Barry Maloney
Edward F. Manzi, Jr.
Mary Jo Marión
Michael McDermott
Samantha McDonald, Esq.
Neil D. McDonough
Kate McEvoy
Thomas McGregor
Joseph McManus
Satya Mitra, Ph.D.
Robert J. Morton
Michael Mulrain
Timothy P. Murray, Esq.
Dave Nordman
James D. O'Brien, Jr., Esq.
Michael V. O'Brien
Andrew B. O'Donnell, Esq.
Deborah Packard
Anthony Pasquale
Luis Pedraja, Ph.D.
Lisa Perrin
Sherri Pitcher
Richard F. Powell, CPA
Diane Power
John Pranckevicius
Stephanie Ramey
Mary Lou Retelle
Vincent D. Rougeau
Kimberly A. Rozak, Esq.
Jochen Salfeld, Ph.D.
Joseph Salois
Paul Scully
J. Robert Seder, Esq.
Amie Shei, Ph.D.
Matt Shwachman
Troy Siebels
Jaclyn Skagerlind
Michael Sleeper
Joshua Lee Smith, Esq.
Peter R. Stanton
Carolyn Stempler
John C. Stowe
Peter Sullivan
Todd Tallman
Steve J. Tyler, P.E.
Bogdan Vernescu, Ph.D.
Seth P. Wall
Jon Weaver
Greg Weiner, Ph.D.
Michael Welch

Staff

Executive Director & CEO:
Paul F. Matthews

Director of Programs & Operations:
Eric R. Kneeland

Research Associates:
Joshua Boucher, Ph.D.
David Cruz Mejía, MPP
Anthony Clough, MPP

Research Interns:
Misk Aljeboure
Anna Walker