City of Cleveland
Climate Risk and Vulnerability Assessment

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City of Cleveland
Mayor’s Office of Sustainability

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Glossary of Terms

Term	Definition	Source
Adaptation	The process of adjusting to new (climate) conditions in order to reduce risks to valued assets.	U.S. Climate Resilience Toolkit Glossary[1]
Adaptive Capacity	The ability of a person, asset, or system to adjust to a hazard, take advantage of new opportunities, or cope with change.	U.S. Climate Resilience Toolkit Glossary
Climate Risk & Vulnerability Assessment	An assessment of the likelihood of current and future climate hazards. It is a critical process for local authorities to complete in order to understand better the environmental and social impacts of climate change on their jurisdictions.	CDP List of Sustainability Definitions[2]
Climate Hazards	An event or condition that may cause injury, illness, or death to people or damage to assets. This report focuses on climate-related hazards, rather than biological (e.g. pandemics) or geological (e.g. earthquakes) hazards.	U.S. Climate Resilience Toolkit Glossary
Community Assets	Assets are the people, resources, ecosystems, infrastructure, and the services they provide and that communities value.	U.S. Climate Resilience Toolkit Glossary
Community Systems	The built, natural, and human networks that provide important services or activities within a community or region.	*Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments*[3]
Representative Concentration Pathway (RCP)	Scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases (GHGs) and aerosols and chemically active gases, as well as land use/land cover. There are four main RCPs which range from below 2°C warming to high (>4°C) warming best-estimates by the end of the 21st century: RCP2.6, RCP4.5 and RCP6.0 and RCP8.5.	IPCC AR5 Synthesis Report Glossary[4]

[1] United States Global Change Research Program (USGCRP), "U.S Climate Resilience Toolkit: Glossary," https://toolkit.climate.gov/content/glossary, accessed March 31, 2024.
[2] Carbon Disclosure Project (CDP), "List of Sustainability Definitions," https://www.cdp.net/en/the-sustainable-economy-glossary, accessed March 31, 2024.
[3] Center for Science in the Earth System, University of Washington and King County, 2007, *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments*, Seattle: The Climate Impacts Group, https://icleiusa.org/wp-content/uploads/2015/06/Preparing-for-Climate-Change-Adaptation-Guidebook.pdf, accessed March 31, 2024.
[4] Intergovernmental Panel on Climate Change (IPCC), 014: Annex II: Glossary [Mach, K.J., S. Planton and C. von Stechow (eds.)]. In: *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Geneva, Switzerland: IPCC, https://apps.ipcc.ch/glossary/, accessed March 31, 2024.

Resilience	The capacity of a community, business, or natural environment to prevent, withstand, respond to, and recover from a disruption.	U.S. Climate Resilience Toolkit Glossary
Risk	The potential for negative consequences where something of value is at stake. One can determine risk by multiplying the probability of a hazard by the magnitude of the negative consequence or loss.	U.S. Climate Resilience Toolkit Glossary
Sensitivity	The degree to which a system, population, or resource is or might be affected by hazards.	U.S. Climate Resilience Toolkit Glossary
Vulnerability	The propensity or predisposition of assets to be affected adversely by hazards. Vulnerability encompasses exposure, sensitivity, potential impacts, and adaptive capacity.	U.S. Climate Resilience Toolkit Glossary

Executive Summary

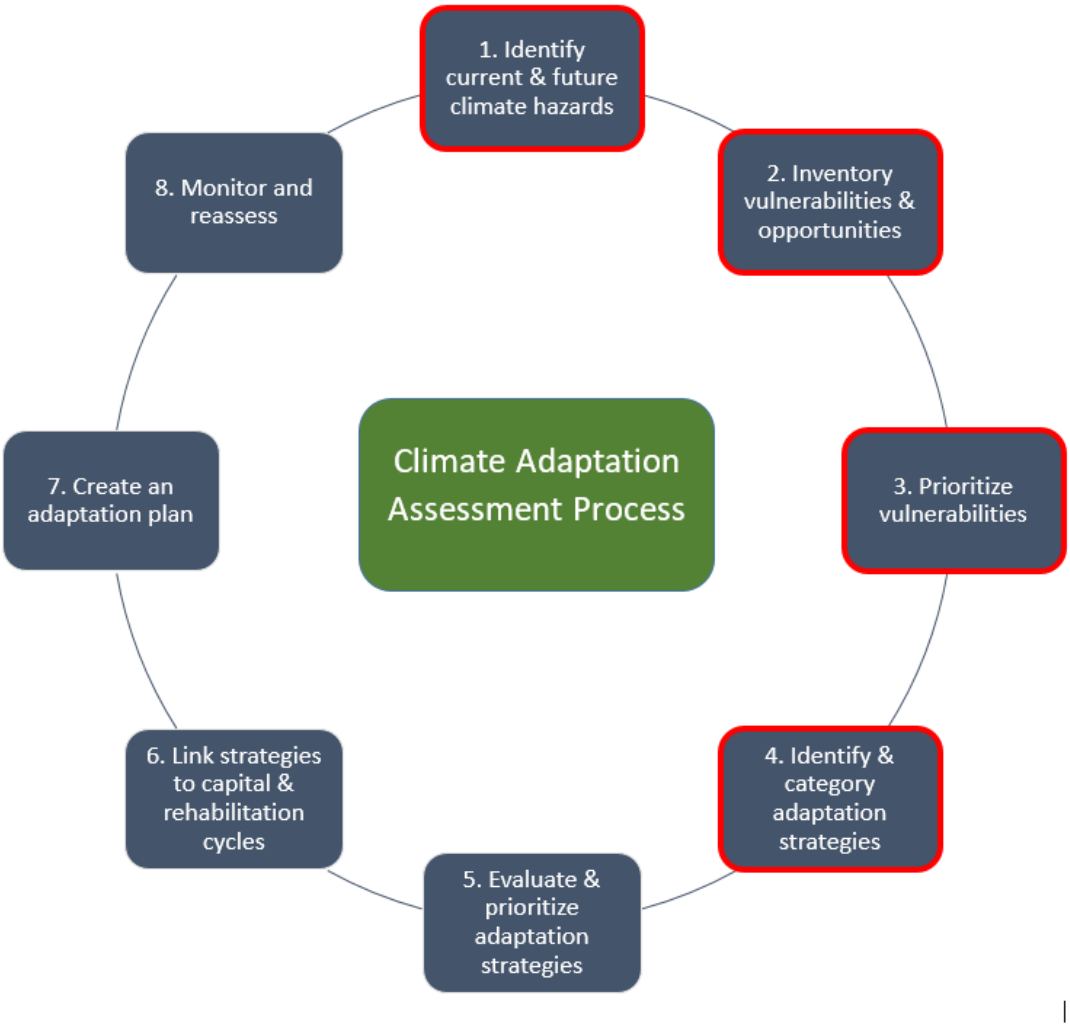
The City of Cleveland initially began preparing for the impacts of a changing climate more than 15 years ago. This effort led to the City's inaugural Climate Action Plan (CAP), which the City published in 2013 and updated in 2018. Through this work, the City remains committed to the principles of equity and climate justice – ensuring the health, safety, and quality of life for all of Cleveland's residents, particularly those living on the frontlines of climate change. As part of its effort to update the CAP, the City of Cleveland has updated its Climate Risk and Vulnerability Assessment (CRVA). A CRVA is an essential component of the municipal climate planning process. This assessment can help inform government officials, departmental staff, and local organizations to assess properly the overall vulnerability of Cleveland's communities to a changing climate and to prioritize adaptation strategies in the updated CAP.

This report introduces an assessment process for the City of Cleveland to utilize as it continues to plan for climate change. An adaptation cycle assesses the capacity of communities to adapt to climate changes, based on anticipated hazards, local vulnerabilities, and proposed strategies (Figure 1). This CRVA completes steps 1-4 of the adaptation cycle, providing a framework for how Cleveland can prioritize areas of vulnerability and identify strategies that address priority climate hazards identified in this report. Ultimately, the City intends to connect directly the City's ongoing actions to its CAP and to identify ongoing opportunities for collaborative action on climate resilience in throughout Cleveland.

This report is broken into six chapters:

- Chapter 1 introduces the report;
- Chapter 2 provides an overview of the CRVA process Cleveland followed, including demographic information and vulnerable neighborhoods;
- Chapter 3 discusses the community engagement process the City followed to inform the development of the CRVA;
- Chapter 4 reviews each of the climate hazards that the City of Cleveland evaluated, including their historic impacts upon the City, projected changes to the hazards under different climate scenarios, the populations most vulnerable to the hazards, and the community assets and systems most vulnerable to the hazards;
- Chapter 5 assesses the factors that challenge the adaptive capacity of Cleveland's residents; and
- Chapter 6 serves as a conclusion.

Figure 1: Climate Adaptation Assessment Process



Through the development of this CRVA, the City has determined the neighborhoods most vulnerable to different climate hazards. It has identified its top four priority climate hazards – poor air quality, extreme heat, heavy precipitation and flooding and severe summer storms – and the population groups and community systems most vulnerable to those hazards. Vulnerable population groups include children, outdoor workers, people experiencing homelessness, people living in low-income and disinvested communities, and people living with medical conditions and disabilities. Vulnerable community systems include community and cultural systems, ecosystem/environmental health, food and agriculture, and public health systems. The City has also highlighted the five factors that most clearly affect the ability of residents to adapt to a changing climate.

This report identifies vulnerabilities throughout the City of Cleveland and identifies opportunities to enhance resilience. Implementing these and other actions to address the community's climate and socioeconomic vulnerabilities in an effective and efficient way will require an "all hands on deck" approach. The CRVA provides a starting point for anyone interested in creating a more resilient, just, and sustainable City of Cleveland.

Chapter 1. Introduction

Climate change represents a real and present threat to the City of Cleveland. Hotter summers, heavy rainfall and flooding, more severe summer storms, and poor air quality threaten to undermine the health, well-being, and quality of life of Clevelanders, particularly the City's most vulnerable residents. In order to help prepare Cleveland for the impacts of a changing climate, the City has developed this Climate Risk and Vulnerability Assessment (CRVA).

This report draws upon the historical data for the region, the most up-to-date climate science and projections, and considerable feedback from City residents and stakeholders to answer the following questions:

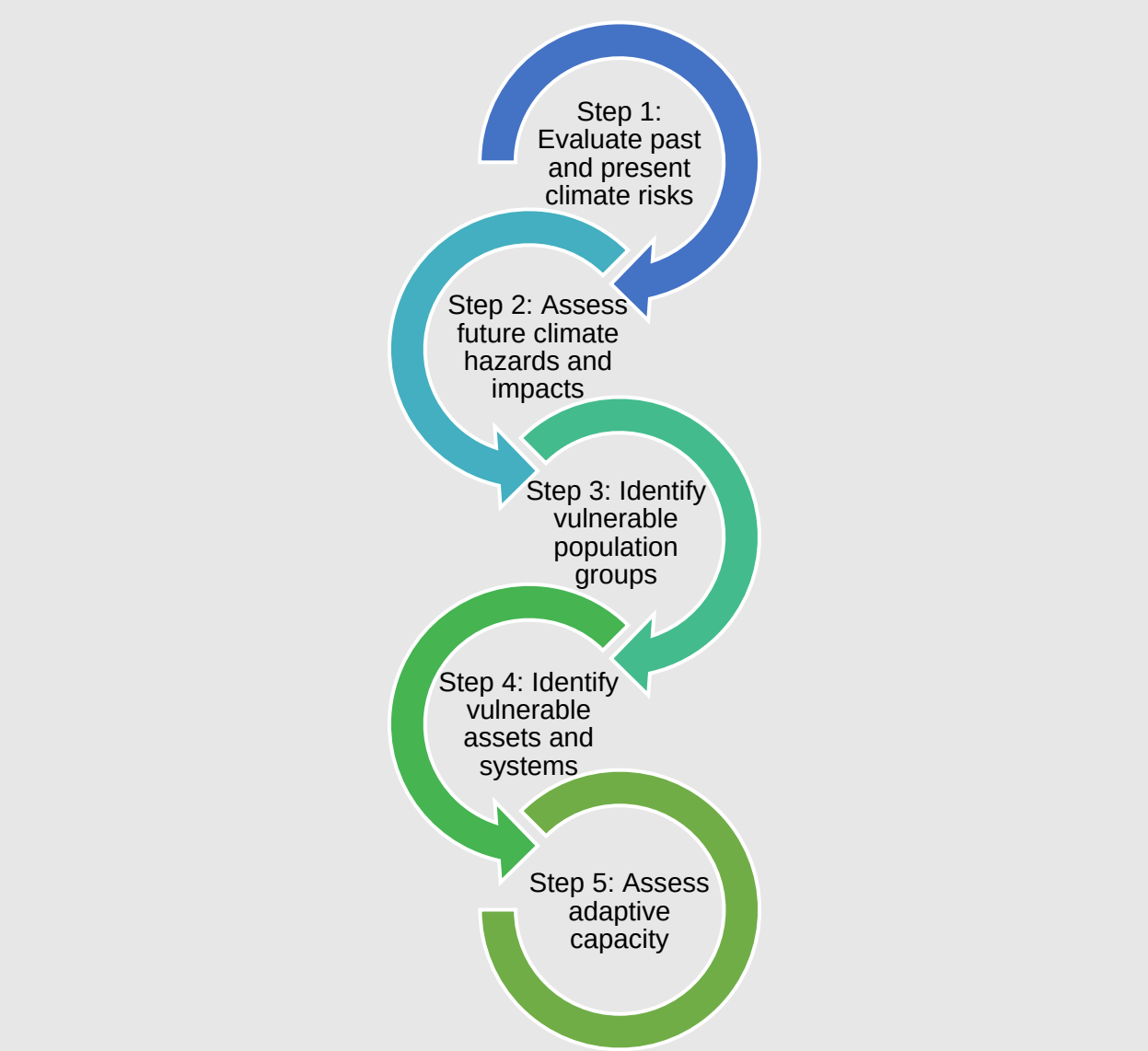
1. What are the primary climate hazards affecting the City of Cleveland, and what are the likely impacts of these hazards;
2. Which community groups are most exposed and vulnerable to these hazards;
3. How sensitive are critical community assets and systems to these hazards;
4. What capacity and means do these community groups and systems have to adapt to the impacts of a changing climate?

By completing this CRVA process, the City of Cleveland was able to combine projected climatic changes with its local demographics and socioeconomic characteristics in order to develop a fuller picture of the City's existing and future vulnerabilities. This information will inform the development of actions that the City and other stakeholders can implement in the coming years to reduce these vulnerabilities and enhance resiliency.

Chapter 2. Climate Vulnerability and Assessment Process

The City of Cleveland developed this CRVA based upon best practices, including guidance from the Global Covenant of Mayors for Climate and Energy (GCoM) and C40 Cities.[5] In line with this guidance, the City followed the CRVA development process outlined in Figure 2.

Figure 2: City of Cleveland's CRVA Development Process

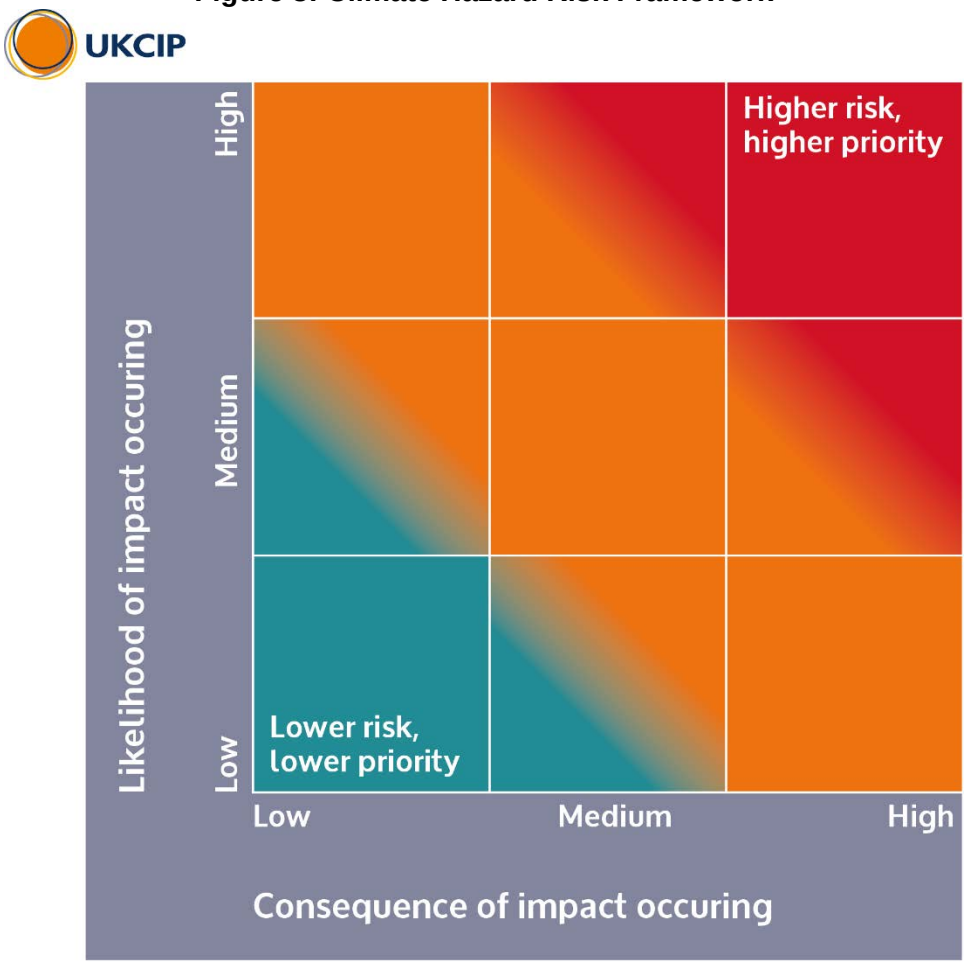


[5] GCoM, 2019, *Guidance Note: Explanatory Note accompanying the Global Covenant of Mayors Common Reporting Framework, Version 9*, Brussels: GCoM, https://www.globalcovenantofmayors.org/wp-content/uploads/2019/04/Data-TWG_Reporting-Framework_GUIDANCE-NOTE.pdf, accessed March 31, 2024.
C40 Cities, 2018, *Climate Change Risk and Assessment Guidance*, https://cdn.locomotive.works/sites/5ab410c8a2f42204838f797e/content_entry5ab410fb74c4833febe6c81a/5b17dd2614ad660612c5dc54/files/C40_Cities_Climate_Change_Risk_Assessment_Guidance.pdf?1541689629, accessed March 31, 2024.

Step 1: Assess future climate hazards and impacts

According to guidance from the Global Covenant of Mayors for Climate and Energy (GCoM), cities must identify climate hazards that have affected them in recent years. Cities must also determine the current level of their risk to these hazards. **Risk** is a function of the probability and consequence of a given hazard. **Probability** defines the likelihood that a climate hazard will affect a community; **consequence**, in turn, explains the extent of the impacts of a climate hazard. Hazards that have a high probability and a high consequence represent a high risk to a city, while hazards with low probability and low consequence are lower risk. Figure 3, below, presents a matrix for understanding the risk of climate hazards according to this framework.

Figure 3: Climate Hazard Risk Framework



Source: United Kingdom Climate Impacts Program (UKCIP) Climate Impacts Wizard, https://www.ukcip.org.uk/wizard/.

Table 1, below, outlines the GCoM guidance that the City of Cleveland used to assess the probability and consequence of different climate hazards.

Table 1: Evaluating Climate Hazard Risk using Probability and Consequence

Category	Level	Definition
Probability	High	Extremely likely that the hazard occurs (greater than 1 in 20 chance of occurring)
	Moderate	Likely that the hazard occurs (between 1 in 20 and 1 in 200 chance of occurring)
	Low	Unlikely that the hazard occurs (between 1 in 200 and 1 in 2,000 chance of occurring)
	Do Not Know	City has not experienced or observed climate hazards in the past or has no ways of accurately reporting this information based on evidence or data
Consequence	High	When it occurs, the hazard results in (extremely) serious impacts to the city and (catastrophic) interruptions to day-to-day life
	Moderate	When it occurs, the hazard results in impacts to your city, but these are moderately significant to day-to-day life
	Low	When it occurs, the hazard results in impacts to your city, but these are deemed less significant (or insignificant) to day-to-day life
	Do Not Know	City has not experienced or observed climate hazards in the past or has no ways of accurately reporting this information based on evidence or data

Source: GCoM *Guidance Note*, https://www.globalcovenantofmayors.org/wp-content/uploads/2019/04/Data-TWG_Reporting-Framework_GUIDANCE-NOTE.pdf.

The City of Cleveland used this guide to evaluate a comprehensive list of hazards, as outlined by CDP.[6] It eliminated those hazards for which the City has no previous history and is unlikely to experience in the future (e.g. wildfires) and those that the City will not experience due to its geographic location (e.g. sea level rise, saltwater intrusion). Based on a series of internal discussions and conversations with key stakeholders, the City of Cleveland ultimately decided to evaluate the risk of 10 climate hazards. These hazards are outlined below.

[6] CDP, 2018, *CDP Cities 2018 Reporting Guidance*, "Hazards and Adaptation," London, https://guidance.cdp.net/en/guidance?cid=4&ctype=theme&idtype=ThemeID&incchild=1&microsite=0&otype=Guidance&, accessed March 31, 2024.

To evaluate the historical and current risks that these hazards pose, the City of Cleveland collected data on each hazard from an array of sources. Primary data sources included, but were not limited to:

- Climate Data Online (CDO) tool from the National Oceanic and Atmospheric Administrations (NOAA) National Centers for Environmental Information (NCEI)
- Great Lakes Integrated Science Assessment (GLISA)
- National Environmental Modeling & Analysis Center (NEMAC) Climate Explorer tool
- National Weather Service (NWS) records
- Risk Factor from the First Street Foundation
- Storm Events Database from NOAA NCEI
- The Fourth and Fifth National Climate Assessments from the U.S. Global Change Research Program (USGCRP)
- U.S. Environmental Protection Agency's (U.S. EPA) Climate Change Indicators in the United States

Climate Hazards in Cleveland

1. Changes to Lake Erie
2. Changing seasonal conditions
3. Drought
4. Extreme heat/heatwaves
5. Heavy precipitation and flooding
6. Insect infestation
7. Invasive plant species
8. Poor air quality
9. Severe summer storms
10. Severe winter weather

In addition to reviewing projected changes in climate hazards, the City of Cleveland consulted with city residents, stakeholders, and subject matter experts. The City conducted a survey of people who live and work in Cleveland from October-November 2023. It also conducted focus groups and public engagement sessions during the fall. For more information on these engagement efforts, please refer to Chapter 3. The results of the analysis of historical and current climate risks are discussed in Chapter 4.

Step 2: Assess future climate hazards and impacts

GCoM guidance instructs cities to consider which climate hazards are likely to affect their jurisdictions in the future due to a changing climate. Similar to Step 1, cities must evaluate their future risk to hazards as a factor of probability and consequence. Cities must detail:

- Changes in the frequency of hazards: increase, decrease, no change, or not known;
- Changes in the intensity of hazards: increase, decrease, no change, or not known; and
- The timescale of these expected changes: immediately (already occurring), short-term (by 2025), medium term (2026-2050), long-term (2051-2100), or not known.

The City of Cleveland examined the future risks of the same 10 hazards identified in Step 1. In order to assess the future risks that these hazards pose, the City collected data from a number of sources, including but not limited to:

- Argonne National Laboratory's Climate Risk & Resilience Portal (ClimRR) tool
- National Environmental Modeling & Analysis Center (NEMAC) Climate Explorer tool
- NOAA's Climate and Hazard Mitigation Planning (CHaMP) Tool
- Risk Factor from the First Street Foundation
- The Fourth and Fifth National Climate Assessments

Where possible, the City of Cleveland gathered and assessed data for each climate hazard for low and high warming scenarios. For the low warming scenario, the City used data from Representative Concentration Pathway (RCP) 4.5; in this scenario, global greenhouse gas (GHG) emissions peak around 2040 and decline thereafter, eventually reaching net zero. Under RCP4.5, global temperatures increase by 1.1-2.6°C, with an average of 1.8°C. For the high warming scenario, the City of Cleveland used data from RCP8.5. In this pathway, which represents a worst-case scenario, emissions continue to increase in the coming decades and fail to decrease before 2100. Under RCP8.5, global temperatures rise by 2.6-4.8°C, with a mean of 3.7°C.[7] Additionally, the City of Cleveland collected data on changes to climate hazards over the medium term (through 2050) and the long term (through 2100).

In addition to reviewing projected changes in climate hazards, the City of Cleveland consulted with city residents, key stakeholders, and subject matter experts. For more information on these engagement efforts, please refer to Chapter 3. The results of the analysis of future climate risks are discussed in Chapter 4.

Step 3: Identify vulnerable population groups

GCoM encourages cities to determine which population groups are most vulnerable to different climate hazards. This exercise allows cities to understand better how climate hazards affect groups differently, which is useful when developing adaptation actions. While climate change will affect all people in some way, the impacts of climate hazards are not distributed evenly across groups. As the USGCRP explains, "While all Americans are at risk, some populations are disproportionately vulnerable, including those with low income, some communities of color, immigrant groups (including those with limited English proficiency), Indigenous peoples, children and pregnant women, older adults, vulnerable occupational groups, persons with disabilities, and persons with preexisting or chronic medical conditions."[8]

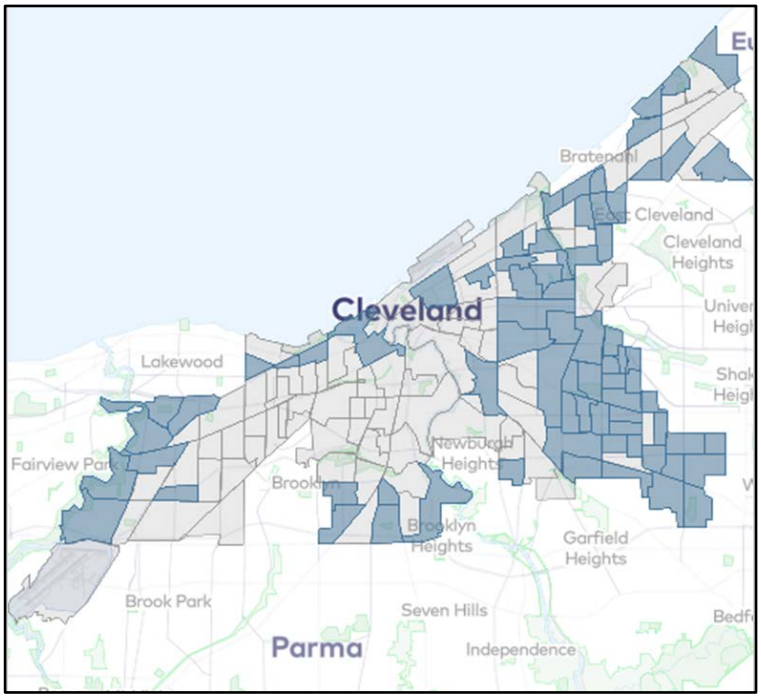
To gain information on vulnerable populations within the City, Cleveland collected data from several sources. These sources included the U.S. Census Bureau's American Community Survey and Headwater Economics' Demographic Profile of Cleveland. The City also gathered feedback from City residents, stakeholders, and subject matter experts through its CRVA survey and public engagement efforts.[9] As part of the survey, the City asked residents to provide feedback on which of nine population groups were most vulnerable to the 10 climate hazards considered. These populations included children, senior citizens, communities of color, people living in low-income/disinvested communities, people experiencing homelessness, people with medical conditions and/or disabilities, people without a car, renters, and outdoor workers.

Demographics of Vulnerable Groups in Cleveland

[7] IPCC, 2014, *Climate Change 2014: Synthesis Report, Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Geneva: IPCCA, https://ar5-syr.ipcc.ch/index.php, accessed March 31, 2024.
[8] USGCRP, 2016, *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*, 2, https://health2016.globalchange.gov/, accessed March 31, 2024.
[9] For more details on this process, please refer to Chapter 3.

Within the City of Cleveland, children under the age of 5 make up 5.8% (21,917) of the population, which is approximately the same share as for the U.S. as a whole.[10] Children are more uniquely vulnerable to a changing climate because, "their immature physiology and metabolism, their unique exposure pathways, their biological sensitivities, and limits to their adaptive capacity" make them highly susceptible to adverse environmental exposures.[11] Just as children are more vulnerable to climate change, so are older individuals. In Cleveland, 14.1% (53,036) of the population is over 65 years of age, slightly below the national average at 16.0%.[12] While being older than 65 can make someone more vulnerable, the 3.4% of Clevelanders over the age of 80 are at even greater risk. Due to higher rates of chronic health issues and disabilities, weakened social networks, and limited financial means, older adults are particularly vulnerable to climate hazards.[13]

Figure 4: Cleveland Census Tracts Where More than 14% of Residents are Over 65 Years Old



Communities of color are also at higher risk. Nearly two-thirds (61.4%) of Clevelanders identify as a race other than white, which is nearly double the national average of 31.8%.[14] People of color are more likely to suffer from preexisting health disparities that can make them particularly vulnerable to the impacts of climate hazards. Due to redlining – the systemic denial of services to residents of certain neighborhoods, typically based on race/ethnicity – and residential segregation, communities of color are also disproportionately located in hazard-prone locations, including floodplains and areas with limited tree cover and more impervious surfaces.[15]

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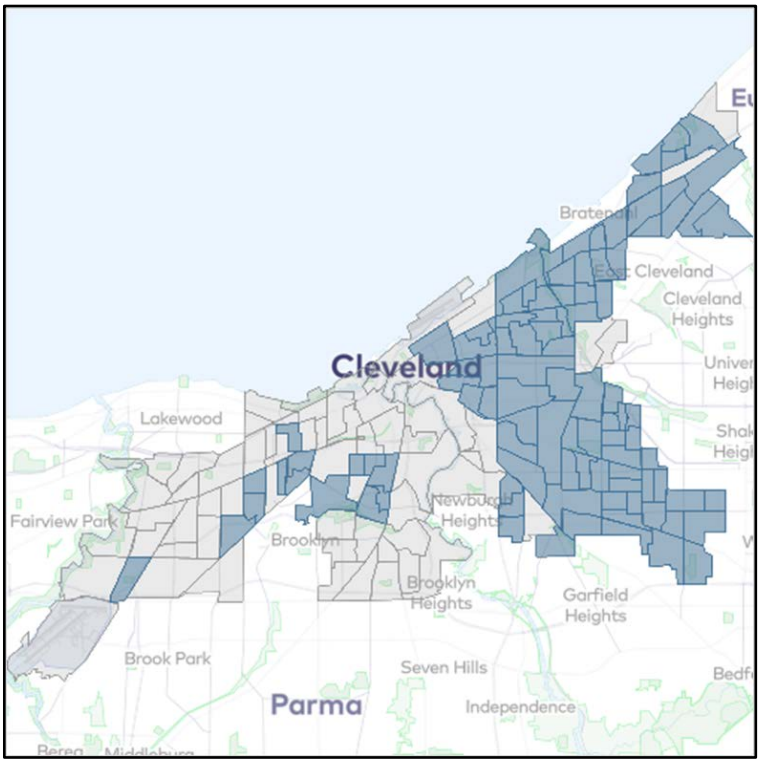
[10] U.S. Census Bureau. "Age and Sex." *American Community Survey, ACS 5-Year Estimates Subject Tables, Table S0101*, 2022, https://data.census.gov/table/ACSST5Y2022.S0101?q=cleveland city, ohio age 2022. Accessed on March 15, 2024.
[11] USGCRP, *The* Impacts *of Climate Change on Human Health*, 255.
[12] U.S. Census Bureau. "Age and Sex." *American Community Survey*.
[13] American Red Cross and American Academy of Nursing, *Closing the Gaps: Advancing Disaster Preparedness, Response and Recovery for Older Adults*, https://www.redcross.org/content/dam/redcross/training-services/scientific-advisory-council/253901-03%20BRCR-Older%20Adults%20Whitepaper%20FINAL%201.23.2020.pdf, accessed March 31, 2024.
[14] U.S. Census Bureau. "Race." *American Community Survey, ACS 5-Year Estimates Detailed Tables, Table B02001*, 2022, https://data.census.gov/table/ACSDT5Y2022.B02001?t=Race and Ethnicity&g=160XX00US3916000. Accessed on March 15, 2024.
[15] Jesdale, Bill M., Rachel Morello-Frosch, and Lara Cushing. "The racial/ethnic distribution of heat risk–related land cover in relation to residential segregation." *Environmental health perspectives* 121.7 (2013): 811-817.

Additionally, because of segregation and racial discrimination, communities of color are often home to locally undesirable land uses (LULUs), including landfills and hazardous waste facilities. Research shows that decision makers intentionally placed LULUs in communities of color, as these communities have fewer resources and power to oppose these actions.[16] Further marginalization of communities of color has continued to attract LULUs, worsening the vulnerabilities of people living in these areas, making them more susceptible to climate hazards and less likely to recover fully in the aftermath of a disaster.

Poverty also plays a big role in vulnerability to climate change. While less than one-tenth of American families (8.8%) live below the poverty line, the share of Cleveland families in poverty is nearly three times higher at 25.6%.[17] Deep poverty, defined as earning less than one-half of the Federal Poverty Line (FPL), is also prevalent in Cleveland, with 14.4% of the residents meeting this threshold.[18] People living in poverty "experience the most negative impacts and weather-related mental distress due to more fragile overall health, reduced mobility, reduced access to health care, and economic limitations that reduce the ability to buy goods and services that could provide basic comfort and mitigate the effects of disasters."[19]

Figure 5: Cleveland Census Tracts Where More than 61.4% of Residents are Non-White

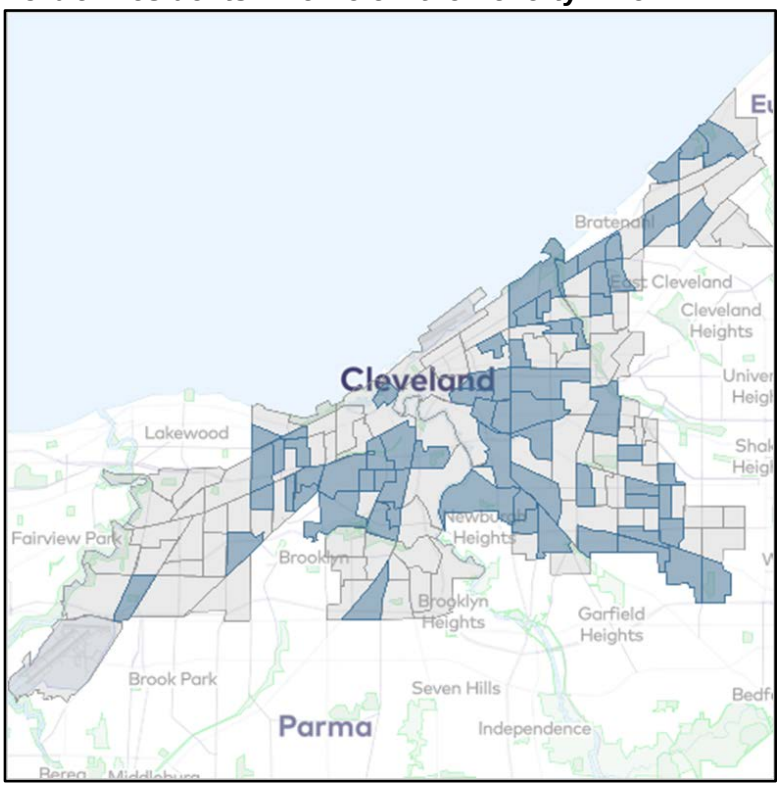


People experiencing homelessness are also extremely vulnerable to climate change. The Point-in-Time Count, a survey of people experiencing homelessness both in and outside of official shelters, occurred on January 24, 2023. This report indicates that there are approximately 1,629 homeless individuals in Cuyahoga County, though this is likely an undercount.[20] According to

[16] Mohai, Paul, and Robin Saha. "Which came first, people or pollution? A review of theory and evidence from longitudinal environmental justice studies." *Environmental Research Letters* 10.12 (2015): 125011.
[17] U.S. Census Bureau. "Poverty Status in the Past 12 Months of Families." *American Community Survey, ACS 5-Year Estimates Subject Tables, Table S1702*, 2022, https://data.census.gov/table/ACSST5Y2022.S1702?q=families poverty cleveland city ohio&g=010XX00US. Accessed on March 15, 2024.
[18] Ibid.
[19] USGCRP, *The* Impacts *of Climate Change on Human Health*, 225.
[20] U.S. Department of Housing and Urban Development (HUD), *2023 CoC Homeless Populations and Subpopulations Report - OH-502: Cleveland/Cuyahoga County CoC*, Washington, DC: HUD,

the Cuyahoga County, there are likely more than 5,000 individuals experiencing homelessness in the County each year.[21] Due to their limited financial resources, lack of access to safe and stable housing, social marginalization, and physical exposure to extreme weather, people experiencing homelessness are more vulnerable to climate hazards. As a result, they "experience it first, they experience it worst, and they generally experience it longest"[22]

Figure 6: Cleveland Census Tracts Where More than 25% of Residents Live Below the Poverty Line



Another population group particularly vulnerable to climate change is people living with medical conditions and/or disabilities. One in five (19.5%) Clevelanders has a disability, above the national average of 12.6%.[23] People with medical conditions and disabilities are more likely to experience factors that heighten their vulnerability, including higher rates of poverty and lower educational attainment.[24] Moreover, people with disabilities remain marginalized in many aspects of society, including climate change and emergency management planning. According to one study, 80% of emergency managers in the US failed to account for the unique needs of disabled persons in their plans, despite federal requirements to do so.[25]

https://files.hudexchange.info/reports/published/CoC_PopSub_CoC_OH-502-2023_OH_2023.pdf, accessed March 31, 2024.

[21] Cuyahoga County Office of Homeless Services, 2023, *Strategic Action Plan for Homelessness: Advancing Pathways to Housing through Equity 2023-2027*, Cleveland: Cuyahoga County, https://hhs.cuyahogacounty.gov/docs/default-source/homeless/homelessplan.pdf?sfvrsn=24ae3e90_3, accessed March 31, 2024.

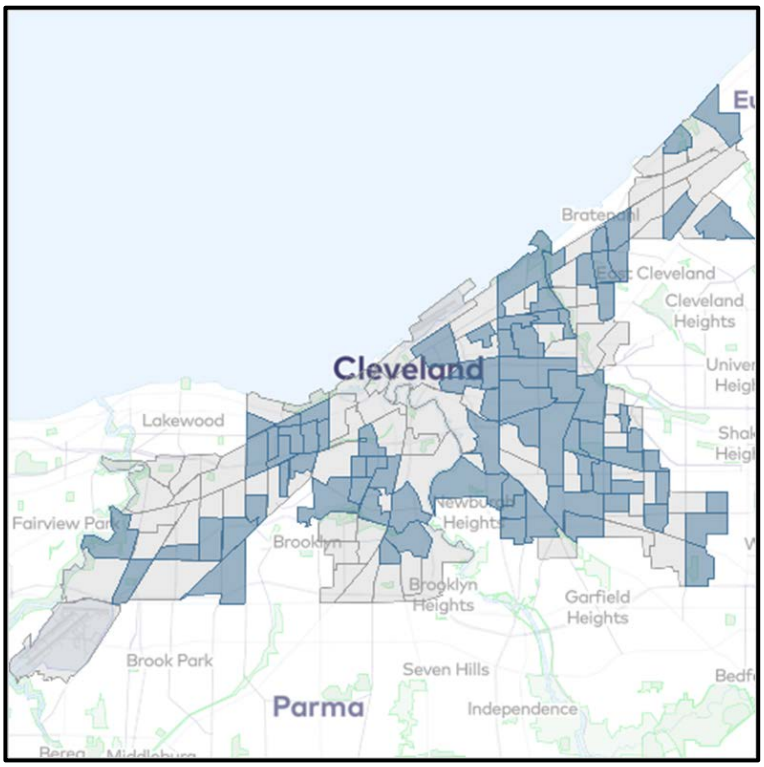
[22] Chilukuri, Siri, July 7, 2023, "How air pollution and the housing crisis are connected." Grist.com, https://grist.org/housing/homeless-people-air-quality-canadian-wildfires/

[23] U.S. Census Bureau. "Disability Characteristics." *American Community Survey, ACS 5-Year Estimates Subject Tables, Table S1810*, 2022, https://data.census.gov/table/ACSST5Y2022.S1810?q=cleveland city, ohio disability 2022, accessed on March 15, 2024.

[24] USGCRP, *The* Impacts *of Climate Change on Human Health.*

[25] Alexander, David, J. C. Gaillard, and Ben Wisner. "Disability and disaster." The Routledge handbook of hazards and disaster risk reduction 1 (2012): 413-423.

Figure 7: Cleveland Census Tracts Where More than 19% of Residents are Disabled



Approximately 5% Cleveland's workforce is employed in the construction, agriculture, forestry, fishing, hunting, and mining industries. Outdoor workers tend to find themselves on the front lines of climate hazards, as they are "often the first to be exposed to the effects of climate change, for longer durations and at greater intensities than the general public."[26] Outdoor workers regularly face dangerous conditions that the public avoids, such as rescuing people trapped by floodwaters or fixing broken power lines after a storm.

People's housing arrangements also significantly influence their vulnerability to climate hazards. In Cleveland, 58.8% (98,818) of the population rents their home. This number is significantly higher than the national average which of 35.4%.[27] Renters are vulnerable because they have less housing security and tend to have fewer resources with which to recover from a disaster. "Further, renters have little to no control over the decision to rebuild, and are at much greater risk of temporary and permanent displacement."[28] In Cleveland, renters are often members of other vulnerable groups. Renters are more likely to be people of color and have less than a high school education, and the median household income for renters is just half that of homeowners.[29]

Lastly, transportation access also affects one's ability to cope with the threat of climate change. Nearly a quarter of Cleveland households (21.9%) do not own a personal automobile, more than double the nationwide mark of 8.3%.[30] Because of the car-centric nature of Northeast Ohio's

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[26] Kiefer, Max, et al. "Worker health and safety and climate change in the Americas: issues and research needs." *Revista Panamericana de Salud Pública* 40 (2016): 193.
[27] U.S. Census Bureau. "Demographic Characteristics for Occupied Housing Units." *American Community Survey, ACS 5-Year Estimates Subject Tables, Table S2502*, 2022, https://data.census.gov/table/ACSST5Y2022.S2502?q=cleveland city, ohio housing tenure 2022, accessed March 15, 2024.
[28] Peacock, Walter Gillis, et al. "Inequities in long-term housing recovery after disasters." *Journal of the American Planning Association* 80.4 (2014): 365.
[29] U.S. Census Bureau. "Demographic Characteristics for Occupied Housing Units." *American Community Survey, ACS 5-Year Estimates Subject Tables, Table S2502*, 2022, https://data.census.gov/table/ACSST5Y2022.S2502, accessed March 15 2024.
[30] U.S. Census Bureau. "Tenure by Vehicles Available." *American Community Survey, ACS 5-Year Estimates Detailed Tables, Table B25044*, 2022,

transportation system, households that do not have access to a personal vehicle may have a harder time evacuating in the wake of a disaster. They may also find it harder to access the distribution of recovery resources, such as food and drinking water.

Evaluating Vulnerability to Climate Hazards in the City of Cleveland

To evaluate which parts of the city are most vulnerable to different climate hazards and to climate change, as a whole, the City of Cleveland analyzed data from two sources: Risk Factor from the First Street Foundation and the Climate Vulnerability Index from the Environmental Defense Fund, Texas A&M University, and Darkhorse Analytics.

Risk Factor is a proprietary model from the First Street Foundation that assesses the risk of different locations – from counties to individual properties – to five climate hazards: air quality, extreme heat, flooding, wildfires, and wind. To get a sense of what areas of the City are exposed most to air quality, extreme heat, flood, and wildfire risks, the City of Cleveland evaluated data for all Census tracts located within City boundaries.[31] Risk Factor provides information on the total number of properties in each Census tract and the risk scores for these properties. The City of Cleveland used these data to develop a weighted average score for each Census tract for each hazard. The results are discussed below.

Extreme Heat Risk

First Street's Heat Factor model evaluates the exposure of a location to extreme heat based upon several factors, including surface temperature, topography, and land cover.[32] Table 2 lists the Census tracts in Cleveland at the highest risk for extreme heat risk, according to these data.

Table 2: Census Tracts Most at Risk of Extreme Heat

2020 Census Tract	Neighborhood
39035117102	Downtown
39035110901	Broadway-Slavic Village
39035104400	Tremont
39035115700	Broadway-Slavic Village
39035116700	Glenville
39035107701	Downtown
39035107802	Downtown
39035117800	Collinwood

https://data.census.gov/table/ACSDT5Y2022.B25044?q=cleveland city, ohio vehicles available 2022, accessed March 15, 2024.

[31] First Street Foundation introduced Air Factor after the analysis for this CRVA was complete. Accordingly, it is not included in this report. Additionally, because Wind Factor focuses on the risks of tropical storms and tornadoes, neither of which poses a significant threat to the City of Cleveland, every Census tract had the same score for wind risk. As a result, the City did not include wind in this analysis.

[32] First Street Foundation, "The Data Behind Heat Factor™," https://riskfactor.com/methodology/heat, accessed March 31, 2024.

Cleveland's Census tracts all have similar scores for heat risk, with 90 tracts scoring at least 3.0 for Heat Risk. The eight tracts identified in Table 3 have weighted average scores above 3.0, while the remaining tracts each scored 3.0. Three of the four tracts in Downtown have scores above 3.0, and two of the nine tracts in Broadway-Slavic Village cross this threshold. Each of these Census tracts is home to a significant amount of heat-related land uses, such as impervious surfaces like asphalt and concrete, which, cover 91.6% of land area, on average.

Flood Risk

Flood Factor model uses a proprietary precipitation model that uses rainfall records from the 21st century to project how extreme precipitation will affect a given location. It includes data on flood risks from the Federal Emergency Management Agency (FEMA) to consider how these changes in rainfall may translate into changes in flood patterns across the country.[33] Table 3 identifies the 10 Census tracts in Cleveland at most at risk for flooding.

Table 3: Census Tracts Most at Risk of Flooding

2020 Census Tract	Neighborhood
39035103300	Ohio City
39035980500	Hopkins
39035980100	Cuyahoga Valley
39035107101	Downtown
39035117900	Euclid-Green
39035117102	Downtown
39035198900	St. Clair-Superior
39035118900	Hough
39035117300	Collinwood
39035107701	Downtown

Cleveland's Census tracts all have a wider range of scores for Flood Risk, with weighted average scores ranging from a low of 1.06 in Buckeye-Shaker to a high of 3.9 in Ohio City. Three of the four tracts in Downtown are ranked in the top 10, while the other seven tracts are distributed across the City. Similar to the top scoring tracts for Heat Risk, impervious surfaces make up the vast majority of land cover. Within these ten tracts, impervious surfaces account for 89.5% of total area.

[33] First Street Foundation, "The Data Behind Heat Factor™," https://riskfactor.com/methodology/heat, accessed March 31, 2024.

Wildfire Risk

First Street's Heat Factor model evaluates the exposure of a given location to wildfires based various criteria, including vegetation, topography, and climate.[34] Table 4 highlights the 10 Census tracts at greatest risk for wildfires in Cleveland, based on this model.

Table 4: Census Tracts Most at Risk for Wildfires

2020 Census Tract	Neighborhood
39035105700	Old Brooklyn
39035980500	Hopkins
39035105602	Brooklyn Centre
39035126100	Euclid-Green
39035107000	Old Brooklyn
39035102102	West Boulevard
39035123602	Kamms
39035122300	Lee-Seville
39035123400	Kamms
39035105400	Brooklyn Centre

Similar to extreme heat, Cleveland's Census tracts all have similar scores for wildfire risk. The City's tracts range from a low 1.0 to a high just 1.15. This range demonstrates that the City of Cleveland faces an extremely low risk from wildfires, even with a changing climate. Of these 10 tracts, two each are located in Old Brooklyn, Brooklyn Centre, and Kamms. With the exception of Census tracts 39035980500 in Hopkins, which is near a major airport, each of these tracts has more tree cover than the city average. The presence of trees can provide fuel for wildfires to spread, especially if the trees are younger and less biologically diverse.[35] Tree cover makes up an average of 29% of land area in these tracts, far higher than Cleveland as a whole (17.9%).[36]

Climate Vulnerability Index for the City of Cleveland

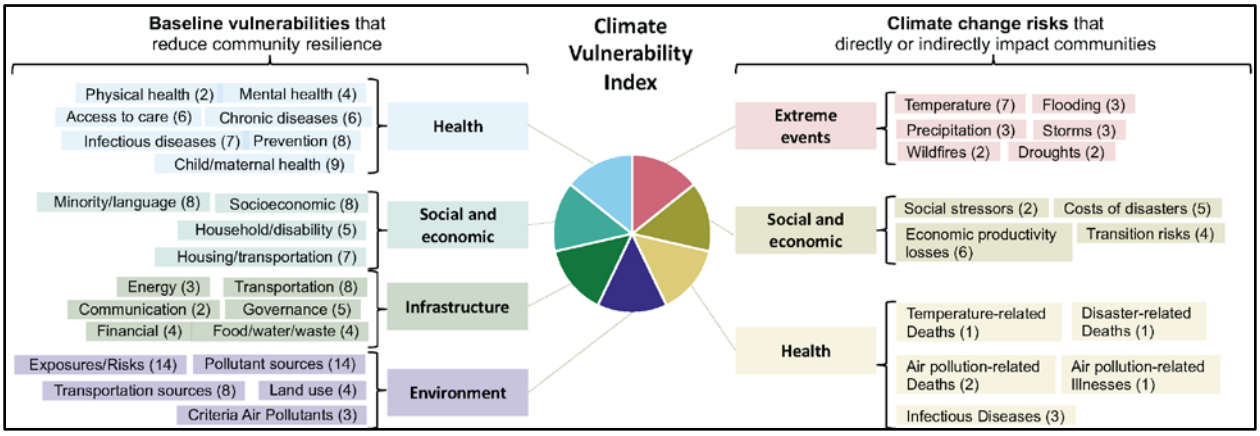
As noted earlier, the fact that a particular neighborhood or community is more (or less) exposed to a given climate hazard does not necessarily mean that it will be more (or less) affected by that hazard. Risk is a function of exposure and vulnerability, meaning that certain highly exposed but resilient groups may fare better during a disaster than highly vulnerable but lightly exposed groups. To understand better how the different vulnerabilities discussed earlier in this

[34] First Street Foundation, "The Data Behind Fire Factor™," https://riskfactor.com/methodology/fire, accessed March 31, 2024.
[35] [35] Christensen, Norm and Jerry Franklin, "New Trees Are No Substitute for Old Trees." *Politico Magazine*, June 11, 2023, https://www.politico.com/news/magazine/2023/06/11/to-fight-wildfire-our-forests-need-to-grow-old-00101360, accessed February 15, 2024
[36] Cuyahoga County Planning Commission, 2019, *Urban Tree Canopy Assessment Update*, https://www.countyplanning.us/projects/urban-tree-canopy-assessment-update/, accessed March 31, 2024.

chapter intersect, the City of Cleveland employed the Climate Vulnerability Index (CVI). This index utilizes 184 datasets to rank over 70,000 Census tracts across the U.S. for their vulnerability to climate change, with each census tract receiving an overall “CVI Score”.

Figure 8, below, explains how the Overall CVI score is developed through the analysis of 184 datasets, which are grouped in two focus areas: baseline vulnerabilities and climate change risks. Baseline vulnerability indicators include variables that undermine climate resilience or constitute existing sources of inequity. CVI further divides these vulnerability buckets into four categories: Health, Social & Economic, Infrastructure, and Environment. Meanwhile, Climate Change risks include both the direct and indirect impacts of a changing climate, which then are divided into three risk categories: Health, Social & Economic, and Extreme Events. These indicators are based on both historical data and climate projections.[37]

Figure 8: Vulnerability and Risk Categories and Component Included in the CVI

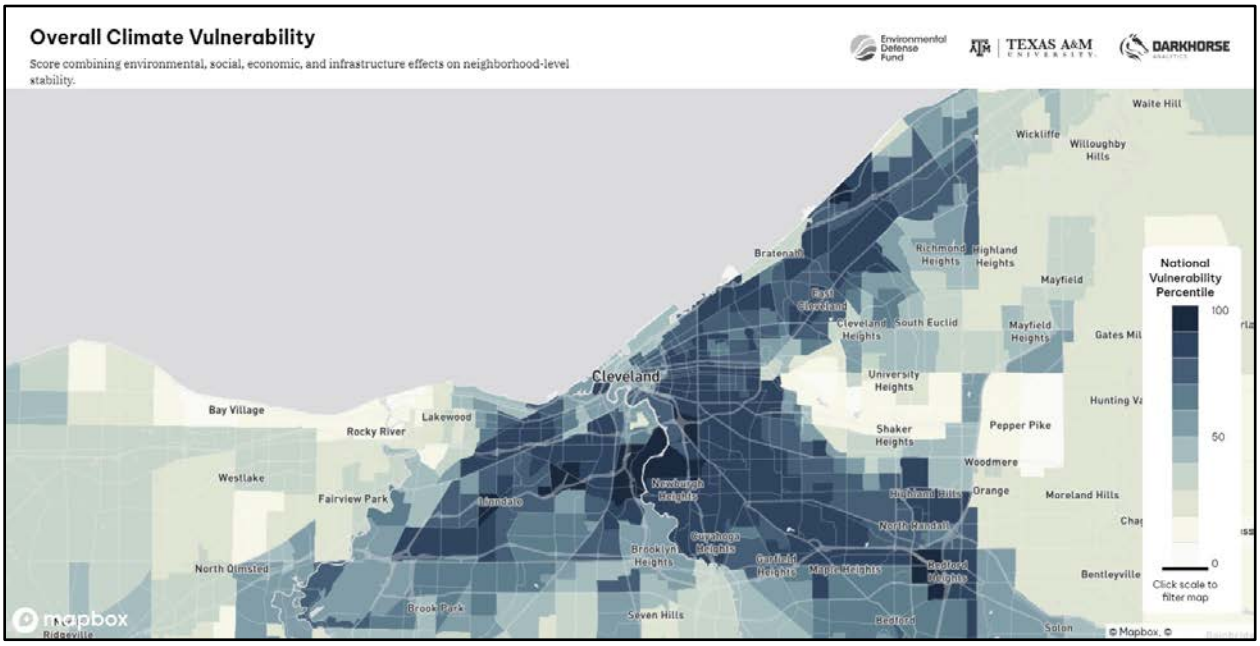


Source: Lewis, P. Grace Tee, et al (2023).

Figure 9, below, illustrates the national percentile rank for Overall CVI Score for every Census tract in the City, while Table 5 identifies the most vulnerable tracts. Each of these Census tracts ranks at the 89th percentile or above, nationally, for overall vulnerability to climate change.

[37] Lewis, P. Grace Tee, et al. "Characterizing vulnerabilities to climate change across the United States." *Environment international* 172 (2023): 107772.

Figure 9: National Percentile Rank for Overall CVI by Census Tract



Source: Climate Vulnerability Index, https://map.climatevulnerabilityindex.org/.

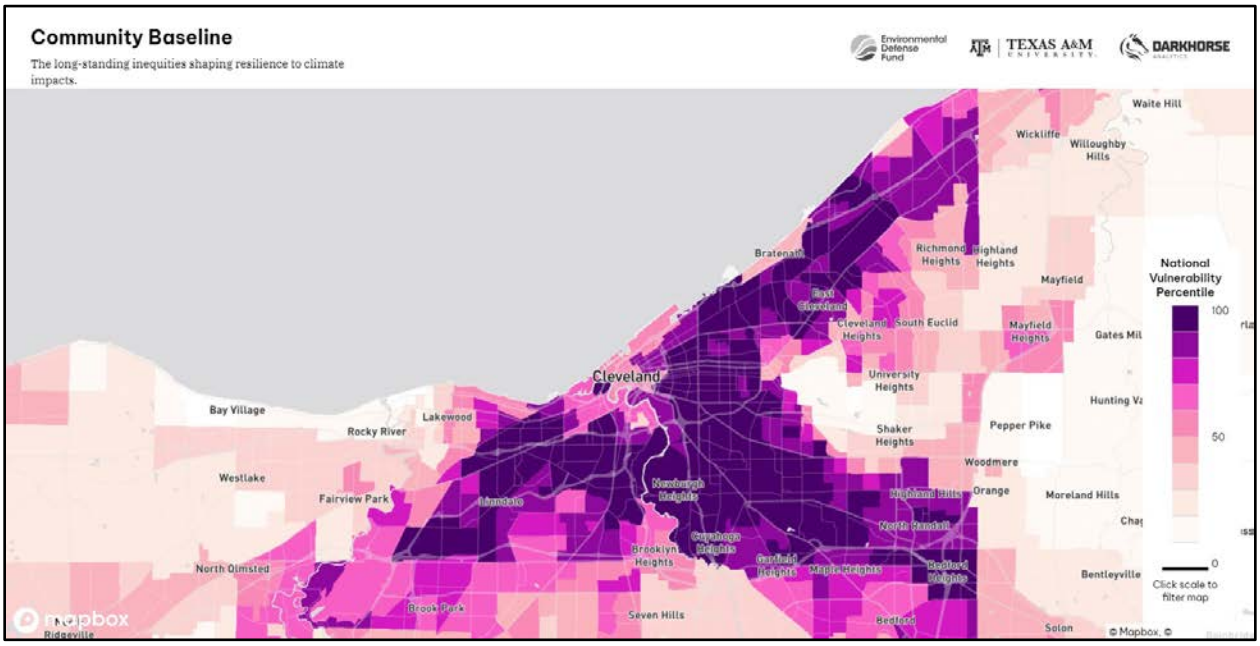
Table 5: Most Vulnerable Census Tracts from CVI

2010 Census Tract	Neighborhood	Overall CVI Score
39035105602	Brooklyn Centre	0.634
39035110901	Broadway-Slavic Village	0.631
39035105100	Stockyards	0.624
39035104800	Tremont	0.620
39035196400	Bellaire-Puritas	0.615
39035110501	Broadway-Slavic Village	0.610
39035117201	North Shore Collinwood	0.609
39035115800	Broadway-Slavic Village	0.607
39035101800	Detroit Shoreway	0.606
39035105400	Brooklyn Centre	0.604

Figure 9, below, maps the national percentile rank for Baseline vulnerability for every Census tract in the City, according to CVI data. Table 6, in turn, identifies the highest scoring Census tracts for this indicator. These tracts are the most vulnerable to the impacts of a changing climate due to current and historical inequities. Each of these Census tracts ranks at the 98th percentile or above, nationally, demonstrating the extreme social vulnerability of Cleveland's neighborhoods to a changing climate. Nearly two-thirds of Cleveland's census tracts (62.9%) rank at or above the 90th percentile nationally for Baseline vulnerability.

The Risk Factor data demonstrate that Cleveland is not as exposed to climate hazards as other parts of the country, given the City's relatively low scores for the hazards. Nevertheless, these vulnerability data emphasize that even minor shocks can have profound impacts for many Cleveland residents. As sociologist Charles Fritz wrote, "No peacetime or wartime disaster in American history has ever produced the aggregate amount of death, destruction, pain, and privation that is experienced in a single day of 'normal' life in the United States, but this fact is rarely recognized except by insurance actuarial specialists and other keepers of vital statistics. The traditional contrast between 'normal' and 'disaster' almost always ignores or minimizes these recurrent and social effects."[38] By focusing on actions to address these significant underlying vulnerabilities, Cleveland can take advantage of its lower climate risks to make itself a climate resilient city.

Figure 10: National Percentile Rank for Baseline Vulnerability by Census Tract



Source: Climate Vulnerability Index, https://map.climatevulnerabilityindex.org/.

[38] Fritz, Charles E, 1961, *Disasters and mental health: Therapeutic principles drawn from disaster studies*, Newark, DE: University of Delaware Disaster Research, 22.

Table 6: Most Vulnerable Census Tracts for Baseline Vulnerability

2010 Census Tract	Neighborhood	Baseline Vulnerability Score
39035105602	Brooklyn Centre	0.742
39035110501	Broadway-Slavic Village	0.731
39035105100	Stockyards	0.730
39035110901	Broadway-Slavic Village	0.729
39035101800	Detroit Shoreway	0.729
39035112100	Hough	0.728
39035196400	Bellaire-Puritas	0.725
39035102800	Clark-Fulton	0.724
39035104800	Tremont	0.721
39035114100	Fairfax	0.721

Step 4: Vulnerable Community Assets and Systems in the City of Cleveland

The City of Cleveland also gathered data on the different community assets and systems that may be vulnerable to climate hazards. Based on guidance from CDP, the City evaluated a list of 16 assets and systems. After internal discussions, it amended and narrowed that list to 12:

1. Community/Cultural (e.g. churches, libraries, community centers)
2. Ecosystems/environmental health (e.g. air quality, water quality, tree cover)
3. Educational (e.g. Cleveland Metropolitan School District, tutoring services, ESL courses, college classes)
4. Energy (e.g. public power and electricity)
5. Food and Agriculture (e.g. food pantry distribution)
6. Housing (City of Cleveland public housing)
7. Industrial (e.g. manufacturing plants, power plants)
8. Information/communications technology (e.g. internet, telephones)
9. Public Health & Safety (e.g. medical care facilities, emergency response services)
10. Solid waste (e.g. garbage collection)
11. Transportation (e.g. RTA transit and bus lines, roadways, sidewalks, bike lanes)
12. Water/wastewater management (e.g. wastewater treatment plant, drinking water)

In order to assess which assets and systems are most at risk from climate hazards, the City surveyed people who live and work in Cleveland. The survey asked respondents to identify the three systems most at risk from each of the 10 climate hazards included in the survey. The City then supplemented these results by asking the same questions during focus groups of stakeholders and subject matter experts and public engagement sessions during the fall.

Step 5: Assess Adaptive Capacity

According to GCoM guidance, the final step in the CRVA process involves evaluating the adaptive capacity of the jurisdiction to climate hazards. Adaptive capacity is the ability of a person, asset, or system to adjust to a hazard, take advantage of new opportunities, or cope with change.[39]

In order to gain feedback on what factors are most important for enhancing (or weakening) adaptive capacity, the City of Cleveland included gathered feedback via a survey, focus groups, and community engagement sessions. For the survey, the City asked respondents to identify the five most important factors affecting their ability to adapt to the impacts of a changing climate. The survey provided 21 options for respondents to select:

1. Access to Basic Services
2. Access to Education
3. Access to Healthcare
4. Budgetary Capacity
5. Community Engagement
6. Cost of Living
7. Economic Diversity
8. Economic Health
9. Government Capacity
10. Having a Place to Live
11. Inequality
12. Infrastructure Capacity
13. Infrastructure Conditions and Maintenance
14. Land-Use Planning
15. Migration
16. Political Engagement and Transparency
17. Poverty
18. Public Health
19. Rapid Urbanization/ Resource Availability
20. Safety and Security
21. Unemployment

For more information on the outcomes of adaptive capacity, please refer to Chapter 5.

Chapter 3. Community Engagement Process

The Mayor's Office of Sustainability (MOS) conducted a community engagement process to inform the development of this CRVA. The MOS prioritized intentional and strategic efforts to engage residents in historically disinvested communities. It also worked to adapt to feedback from residents and partners throughout the process. The MOS used multiple engagement strategies to gain input on how Cleveland communities experience climate hazards. It conducted a public survey and held four in-person public engagement sessions to gain input from populations that did not participate in the survey process.

The MOS used various communication channels to distribute the community survey in both paper and online formats (Survey Monkey). MOS and its community partners included communications materials and recordings that walked residents through how to complete the survey and explained why it was important for community members to provide their input. MOS distributed paper copies of the survey, complete with instructions on how to disseminate and return completed versions, to each open Neighborhood Resource and Recreation Center and to several community development corporations (CDCs). MOS' Outreach and Education Manager handed out paper survey copies during two community events and provided instructions to

[39] USGCRP, "U.S Climate Resilience Toolkit: Glossary."

community members on completing it. MOS also sent the electronic survey and PDF versions of the paper survey to both external partners (including CDCs, Cleveland Environmental Advocacy Coalition member community based organizations, and MetroHealth) and internal City contacts (including the Community Development Department, City Council, and the Community Relations Board). MOS collected survey responses from October 9 – November 17, 2023. The City of Cleveland received 971 total responses to the survey. After the elimination of responses that were incomplete, invalid, or from people who neither live nor work in Cleveland, there were 399 valid responses. The sample size was statistically significant, and the survey had a margin of error of ±5%. A copy of the complete survey questions is available in Appendix A.

Among survey respondents, 48% identified as male, 45% as female, and 4% as gender non-binary. Individuals aged 25-34 (38%), 35-49 (25%), and 18-24 (14%) accounted for more than three-quarters of survey responses, while individuals aged 50-65 (11%), over 65 (10%), and under 18 (1%) made up the remainder. Sixty-two percent of responses came from individuals who identified as white, followed by Black or African American (11%), Asian or Asian American (9%), Native Hawaiian or other Pacific Islander (5%), American Indian or Alaska Native (4%), and Hispanic or Latino (4%). Thirty-seven percent of respondents reported earning $50,000-$74,999 per year, followed by $25,000-$49,999 (23%), $75,000-$99,999 (14%), over $100,000 (11%), $0-$24,999 (10%), and prefer not to say (4%). Nearly half (48%) of responses came from individuals who had earned at least a Bachelor's degree, while another third (35%) came from individuals who completed some college or an Associate's degree. Thirteen percent or respondents completed high school, while 2% did not respond, and 1% did not complete high school. Lastly, nearly half of respondents (48%) reported owning a home, while another one-quarter (23%) indicated they were renters. The remaining 29% lived with friends or family, lived in student housing, or did not permanent housing. A majority (52.1%) of responses came from residents of low-income and disadvantaged communities (LIDAC).

From November – December 2023, MOS scheduled four public engagement sessions for residents to provide input for the CRVA. MOS staff recognized that the demographics of survey respondents did not closely mirror those of Cleveland residents as a whole, so staff targeted these sessions in neighborhoods that either had lower electronic and paper survey response or that were more vulnerable to key hazards. These sessions incorporated information from the survey, feedback from community stakeholders, and information from previous engagement efforts in Cleveland's neighborhoods. The MOS scheduled two sessions in the Union-Miles and Central-Fairfax neighborhoods, as both had low survey response rates. One session occurred in Downtown, given its high flood risk, according to Risk Factor data. Lastly, MOS opted to host the final session in Clark-Fulton, due to

Feedback from participants at the December 3, 2023 engagement session in Union-Miles.

its large Hispanic and non-native English speaking population.

MOS worked closely with the CDCs in each neighborhood to ensure that low-income and disadvantaged Clevelanders could participate fully in each session. Two engagement sessions occurred outside of normal work hours, while the other two sessions occurred at times recommended by the neighborhood CDCs. One session took place from 1:30-3:00 pm to accommodate the needs of elderly residents. MOS provided each attendee with food and an all-day transit pass. Engagement sessions occurred at the Cleveland Public Library Main Branch (Downtown neighborhood), Killingsworth Meeting Place (Union-Miles neighborhood), Bridge City CLE (Clark-Fulton neighborhood), and Friendly Inn Settlement House (Central-Fairfax neighborhood). Local community organizers and CDC staff familiar with the area and skilled in outreach helped to promote each session to members of the community. A Spanish interpreter was available at the engagement session located in Clark-Fulton. The majority (56%) of participants in these sessions were residents of LIDAC areas.

Each session followed a similar format and lasted around 90 minutes. As participants came into the meeting room, they were encouraged to sign in; a few participants signed in but did not include their names to preserve anonymity. MOS and CDC staff encouraged attendees to help themselves to refreshments, introduce themselves to their neighbor, and answer an icebreaker question. Staff then delivered a PowerPoint presentation that introduced the concept of climate change and described the climate hazards affecting Cleveland. After the presentation, the attendees separated into breakout groups, where they discussed the vulnerability of Cleveland's neighborhoods, populations, assets, and systems.

When there were more than nine attendees, MOS divided the room into three groups. Each group discussed one of three topics: vulnerable neighborhoods, vulnerable populations, and vulnerable assets and systems. Staff members identified climate hazards that were the largest concerns for the neighborhood expressed in the community survey. They then posed questions to discuss the impacts of these climate hazards and to gauge whether the hazards were of concerns for the participants. One MOS staff member attended each session. Participants shared their feedback verbally and by writing thoughts on Post-It notes. The discussion period for each topic lasted approximately 15 minutes before participants rotated to the next, although there was some variation based on the size of the session. Following the breakout discussions, the facilitator asked questions to the larger group on how the cope with climate hazards. The facilitator also asked attendees to identify the climate actions they consider most important for the City of Cleveland. Participants provided their feedback verbally and by placing written responses on poster boards. If at any point participants had questions or comments that were not directly relevant to the conversation or that staff could not address at that time, facilitators encouraged them to write them down to revisit later.

Chapter 4. Climate Hazards Overview

This chapter outlines each of the 10 climate hazards that the City of Cleveland analyzed in detail. Based on the results of the survey, focus groups, and public engagement sessions during Fall-Winter 2023, there are four priority climate hazards for the City of Cleveland: Poor Air Quality, Extreme Heat, Heavy Precipitation and Flooding, and Severe Summer Storms. The City has combined Heavy Precipitation and Flooding with Severe Summer Storms due to their

substantial overlap. This section provides a detailed analysis of these hazards before providing briefer overview of the six other hazards analyzed: Changes to Lake Erie, Changing Seasonal Conditions, Drought, Insect Infestation, Invasive Plant Species, and Severe Winter Weather.

Table 7 details the risk scores for each of these hazards, including the average scores for likelihood and consequence, while Figure 10 charts these hazards on the risk matrix. Table 8, in turn, outlines the projected changes to the intensity and frequency of each of these climate hazards in Cleveland due to climate change. It also describes the timeline on which these projected changes are likely to take place.

Table 7: Combined Risk Scores for Climate Hazards in Cleveland

Climate Hazard	Likelihood	Consequence	Total Risk
Poor Air Quality	2.43	2.49	6.06
Extreme Heat	2.34	2.33	5.45
Heavy Precipitation & Flooding	2.28	2.26	5.16
Severe Summer Storms	2.29	2.22	5.09
Severe Winter Weather	2.26	2.19	4.97
Changing Seasonal Conditions	2.24	2.07	4.63
Changes to Lake Erie	2.06	2.03	4.18
Drought	1.97	1.97	3.90
Insect Infestation	1.79	1.81	3.24
Invasive Plant Species	1.73	1.73	3.00

Figure 11: Risk Matrix for Climate Hazards in Cleveland

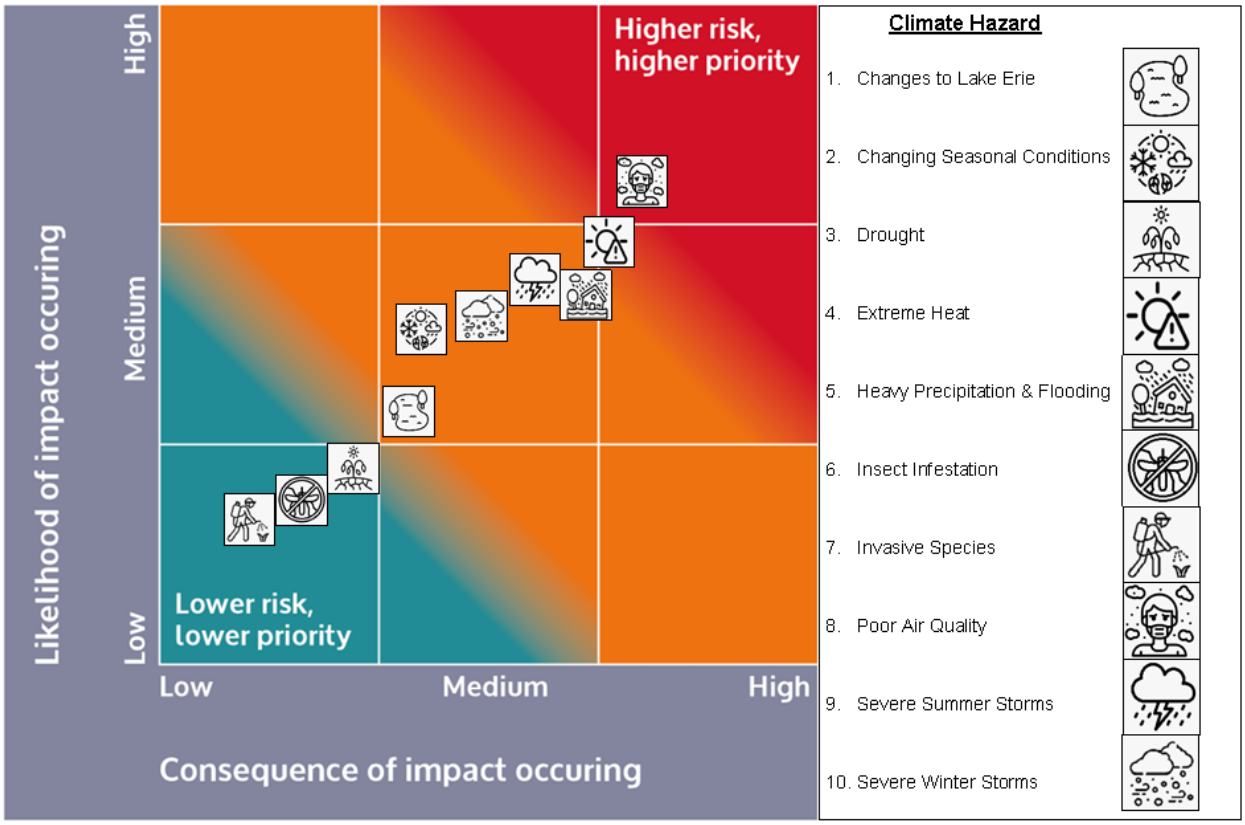


Table 8: Projected Changes to Climate Hazard Impacts in Cleveland

Climate Hazard	Intensity	Frequency	Timescale
Poor Air Quality	Increase	Increase	Immediate
Extreme Heat	Increase	Increase	Medium Term (2026-2050)
Heavy Precipitation & Flooding	Increase	Increase	Short Term (2025)
Severe Summer Storms	Increase	Increase	Medium Term (2026-2050)
Severe Winter Weather	Decrease	Decrease	Medium Term (2026-2050)
Changing Seasonal Conditions	Increase	Increase	Medium Term (2026-2050)
Changes to Lake Erie	Increase (algal blooms), Decrease (ice cover)	Increase (algal blooms), Decrease (ice cover)	Immediate
Drought	Increase	No change	Medium Term (2026-2050)
Insect Infestation	Increase	Not known	Medium Term (2026-2050)
Invasive Plant Species	Increase	Not known	Medium Term (2026-2050)

Table 9 details projected changes in climate conditions in Cleveland through the end of the century, including average daily temperatures, precipitation, and growing season. It also details the percentage change of these conditions, compared to the 1950-2013 average.

Table 9: Projected Changes in Climate Conditions in Cleveland through 2100

Year	1950-2013	2030s		Mid-Century		End of Century	
	Value	Value	% Change	Value	% Change	Value	% Change
Average Daily Low Temperatures							
Low	40.9	44.2	8.1%	45.4	11.0%	47	14.9%
High		44.4	8.6%	46.9	14.7%	51.9	26.9%
Average Daily High Temperatures							
Low	59.3	62.9	6.1%	64.2	8.3%	65.7	10.8%
High		63.2	6.6%	65.6	10.6%	70.7	19.2%
Number of days per year with a maximum temp > 90 F							
Low	6.7	23.3	247.8%	31.1	364.2%	40.7	507.5%
High		26.1	289.6%	41.3	516.4%	81.6	1117.9%
Number of days per year with a minimum temp <32 F							
Low	120.7	102.5	-15.1%	95.9	-20.5%	85.8	-28.9%
High		102.2	-15.3%	87.4	-27.6%	58	-51.9%
Total annual precipitation (in.)							
Low	38.76	38.88	0.3%	39.93	3.0%	39.86	3.0%
High		39.16	1.0%	40.33	4.1%	41.93	8.2%
Number of days per year with > 1 inch precipitation							
Low	3.6	3.6	0.0%	4	11.1%	4.1	13.9%
High		3.7	2.8%	4.3	19.4%	5.2	44.4%
Number of growing degree days per year							
Low	2,887.5	3,700	28.1%	3,900	35.1%	4,300	48.9%
High		3,700	28.1%	4,200	45.5%	5,500	90.5%

Source: NEMAC, "The Climate Explorer."

Poor Air Quality

Past and Current Impacts of Poor Air Quality

The City of Cleveland has a long history of poor air quality. Records demonstrate that the City faced persistent issues with air pollution, particularly smoke, dating back to the mid-19th century. In 1882, Cleveland become one of the first cities in the U.S. to pass an ordinance for smoke abatement.[40] Despite these early efforts to regulate air pollution, progress remained elusive for decades. Cleveland's air pollution challenges continued to worsen throughout the 20th century,

[40] Cleveland Department of Public Health, "Cleveland Historical Air Quality," https://www.clevelandhealth.org/programs/air/history/, accessed March 31, 2024.

prompting the City to create the Air Pollution Control Division in 1947. Following the passage of the 1970 Clean Air Act (CAA), air quality in Cleveland began to improve significantly. From 1990-2021, concentrations of carbon monoxide (CO), nitrogen dioxide (N_2O), coarse particulate matter (PM_{10}), and sulfur dioxide (SO_2) fell by 69%, 44%, 27%, and 80%, respectively.[41]

Wildfire smoke obscures downtown Cleveland on June 28, 2023.

Despite these improvements, Cleveland continues to struggle with persistent air quality challenges. The City continually ranks as one of the country's "Asthma Capitals," and it has the seventh highest asthma rate in the country.[42] During 2021, 12.6% of adults had asthma in Cleveland, far higher than the national average, and the pediatric asthma rate was above 15% in certain East Side neighborhoods.[43] Research has shown a strong relationship between air pollution levels and pediatric asthma in Cleveland, as children living in the most polluted areas are twice as likely to suffer from asthma.[44] Across Northeast Ohio, air pollution was responsible for 639-1,439 premature deaths, 60-546 nonfatal heart attacks, 12,975 asthma exacerbations, and more than 63,000 lost workdays during 2016.[45]

While ozone levels fell 19% from 1900 to 2022, they actually rose slightly from 2013 to 2022.[46] In August 2018, the U.S. EPA designated a seven-county region in Northeast Ohio as a marginal nonattainment area for the 2015 National Ambient Air Quality Standard (NAAQS) for ozone.[47] The region failed to meet the NAAQS by its August 3, 2021 attainment date, and U.S. EPA bumped it up to moderate nonattainment on October 7, 2022.[48] Northeast Ohio will not meet the NAAQS again by August 3, 2024, meaning it is likely that U.S. EPA will bump it up to serious nonattainment for the first time in the region's history.

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[41] Northeast Ohio Areawide Coordinating Agency (NOACA), 2023, *2022 Air Quality Trends Report*, Cleveland: NOACA, https://www.noaca.org/home/showpublisheddocument/29603/638157747909470000, accessed March 31, 2024.
[42] Asthma and Allergy Foundation of America (AAFA), 2023, *2023 Asthma Capitals*, Arlington, VA: AAAF, https://aafa.org/asthma-allergy-research/our-research/asthma-capitals/, accessed March 31, 2024.
[43] Data from Healthy Northeast Ohio, "Community Dashboard," https://www.healthyneo.org/indicators, accessed March 31, 2024.
[44] Khatri, Sumita B., et al. "Associations of air pollution and pediatric asthma in Cleveland, Ohio." *The Scientific World Journal* 2021 (2021).
[45] NOACA, *2022 Air Quality Trends Report.*
[46] U.S. EPA, "Air Quality System," https://www.epa.gov/aqs, accessed March 31, 2024.
[47] U.S. EPA, 2018, "8-Hour Ozone (2015) Designated Area/State Information with Design Values," https://www3.epa.gov/airquality/greenbook/jbtcw.html, accessed March 31, 2024.
[48] Determinations of Attainment by the Attainment Date, Extensions of the Attainment Date, and Reclassification of Areas Classified as Marginal for the 2015 Ozone National Ambient Air Quality Standards, 87 F.R. 60897, https://www.federalregister.gov/d/2022-20460, accessed March 31, 2024.

Because ozone forms most readily on calm, warm summer days, climate change is exacerbating the City's ozone challenges. The number of these stagnant air days has risen to 25 per year by 2021, from 14 per year in 1973.[49] As a result, the number of days on which Cleveland exceeds the ozone NAAQS has remained static over the past decade, even as emissions of the pollutants that form ozone – nitrogen oxides (NO_x) and volatile organic compounds (VOCs) – have continued to fall. This effect was starkest during 2020, when COVID-19 mitigation measures dramatically reduced emissions, but the number of ozone exceedance days increased, compared to 2019.[50] Increases in wildfire activity in other regions may also increase ozone pollution in Cleveland. On June 29, 2023, the region registered its highest ozone concentrations since 2011 due to smoke from Canadian wildfires.

Concentrations fine particulate matter ($PM_{2.5}$) in Cleveland have decreased 37% since monitoring began in 2000.[51] This is a positive trend, and the region currently complies with the 2012 NAAQS for $PM_{2.5}$; however, this rate of improvement has slowed in recent years. While $PM_{2.5}$ levels decreased by 33.5% from 2000 to 2009, that rate slowed to 22.9% from 2013 to 2022.[52] Recent research suggests that wildfire smoke from outside of the region is likely contributing to this stagnation in pollution levels.[53] Smoke from these wildfires is already having a negative impact on public health in the region, as a recent study estimated that wildfires in the western U.S. affected seven million Ohioans and caused 125 premature deaths from 2012-2014.[54] The impact of wildfire smoke was particularly apparent during summer 2023, when repeated incursions of smoke from fires across Canada undermined air quality in Cleveland on several occasions. Cleveland experienced its worst and second worst days for air quality on record on June 28 and June 29, 2023, respectively.

As part its public engagement efforts, the City of Cleveland asked people to rank the impact of poor air quality on the City. On average, respondents gave poor air quality a rating of 2.4 for likelihood and 2.5 for consequence. Poor air quality received a total risk score of 6.1, making it the top scoring climate hazard for Cleveland.

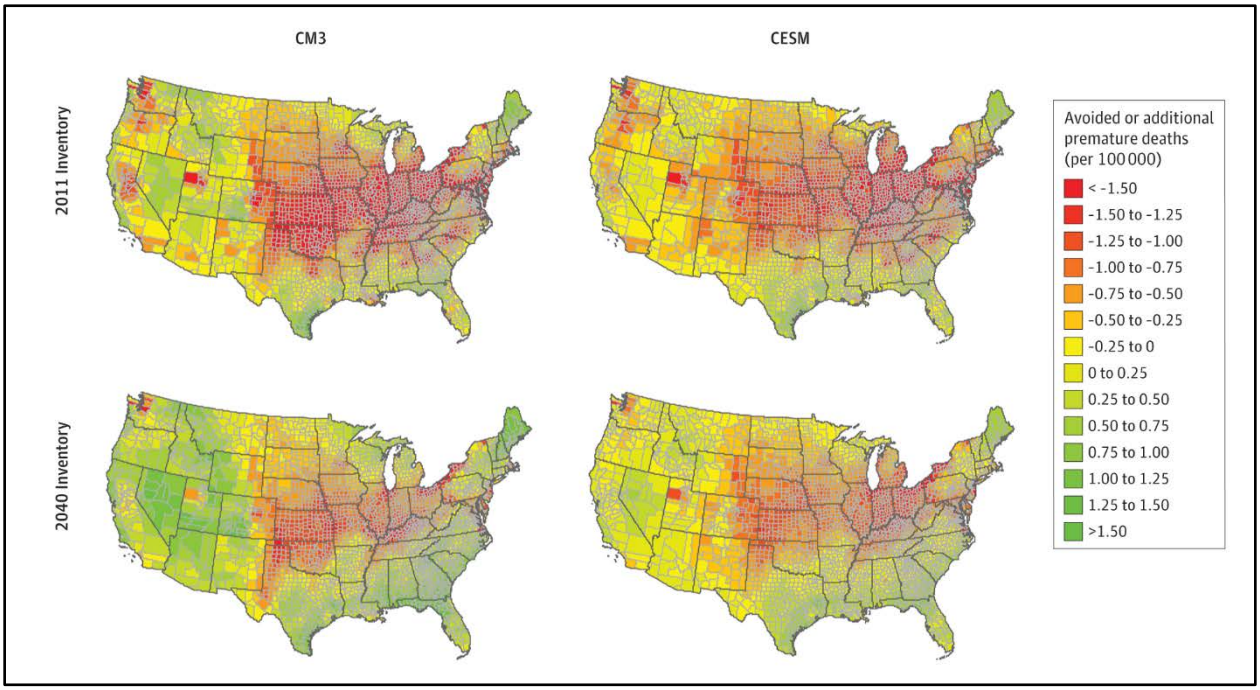
Future Impacts of Poor Air Quality

Climate change will likely continue undermine air quality in Cleveland over the coming decades. As summer temperatures rise and stagnant air events become more common, the City of Cleveland will likely see ozone levels remain stable or potentially increase. According to U.S. EPA, the "climate penalty" (i.e. the impact of higher temperatures on ozone levels) may be particularly bad for Cleveland, as average daily ozone levels will likely increase by 1-5 parts per

[49] Climate Central, 2022, "Summer Air: Hot, Stagnant, Polluted," https://www.climatecentral.org/climate-matters/stagnant-air, accessed March 31, 2024.
[50] NOACA, *2022 Air Quality Trends Report.*
[51] Ibid.
[52] U.S. EPA, "Air Quality System," https://www.epa.gov/aqs, accessed March 31, 2024.
[53] Burke, Marshall, et al. "The contribution of wildfire to PM2. 5 trends in the USA." *Nature* 622.7984 (2023): 761-766.
[54] Pan, Shuai, et al. "Quantifying the premature mortality and economic loss from wildfire-induced PM2. 5 in the contiguous US." *Science of The Total Environment* 875 (2023): 162614.

billion (ppb) and up to 10 ppb by 2050 and 2100, respectively.[55] Under low (RCP4.5) and high (RCP8.5) warming scenarios, ozone-related mortality rates may rise by more than 50% for populations in the Midwest.[56] The share of Cleveland residents exposed to three or more days of harmful ozone pollution may increase by 69% and 249% under RCP4.5 and RCP8.5, respectively.[57]

Figure 12: Estimated Premature Deaths Associated With Ozone Concentrations in 2095

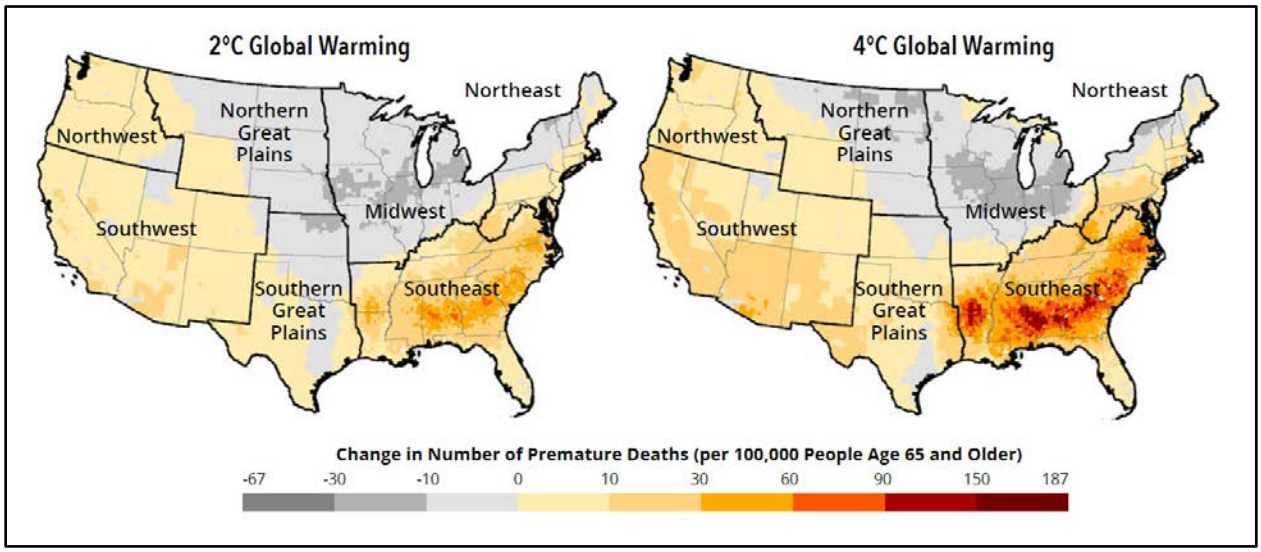


Source: Nolte, et al (2021).

While the evidence is more mixed, U.S. EPA projects that increased precipitation may reduce $PM_{2.5}$ levels in the Midwest, with annual $PM_{2.5}$ concentrations falling by 1.5 micrograms per cubic meter ($\mu g/m^3$). Any decrease in $PM_{2.5}$ levels would improve public health in Cleveland, as it reduce premature deaths and the incidence of asthma.[58] Under a low warming scenario (RCP4.5), $PM_{2.5}$-related mortality is projected to fall slightly (approximately nine fewer premature deaths per year by 2050). However, this reduction is not a foregone conclusion. In higher warming scenarios (e.g. RCP8.5), $PM_{2.5}$ levels may actually increase in Cleveland, and $PM_{2.5}$-related mortality could rise by 22 premature deaths per year.[59] This increase in $PM_{2.5}$ may be due to higher risks of wildfires outside of Ohio.

[55] Nolte, Christopher G., et al. "Regional temperature-ozone relationships across the US under multiple climate and emissions scenarios." *Journal of the Air & Waste Management Association* 71.10 (2021): 1251-1264.
[56] U.S. EPA, 2021, *Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts* www.epa.gov/cira/social-vulnerability-report, accessed February 6, 2024.
[57] Dionisio, Kathie L., et al. "Characterizing the impact of projected changes in climate and air quality on human exposures to ozone." *Journal of exposure science & environmental epidemiology* 27.3 (2017): 260-270.
[58] U.S. EPA, 2021, *Climate Change and Social Vulnerability*.
[59] Ibid.

Figure 13: Projected Changes in Annual Premature Deaths due to Climate-Driven Effects on PM2.5



Source: U.S. EPA, *Climate Change and Social Vulnerability in the United States.*

Populations Vulnerable to Poor Air Quality

While everyone is susceptible to the negative impacts of poor air quality, certain groups are uniquely vulnerable to this hazard. In the survey and engagement sessions, the City of Cleveland asked respondents to identify the three groups most vulnerable to poor air quality. Based on this feedback, the three populations most vulnerable to poor air quality in Cleveland are outdoor workers, people experiencing homelessness, and children. Given their direct and prolonged exposure to ambient air pollution, outdoor workers are more likely to suffer adverse health impacts, including respiratory illnesses and allergic reactions.[60] Because people working outdoors often work in physically taxing professions, their elevated respiration rates ensure that they inhale larger amounts of pollution, further increasing their vulnerability to its effects.[61] People experiencing homelessness also live on the frontlines of poor air quality, particularly those who stay in encampments. This underlying exposure is compounded further, as many homeless individuals reside in areas that already have higher ambient pollution levels, such as under bridges and along heavily trafficked roadways.[62] Lastly, children are particularly at risk from poor air quality, as they have smaller lungs and breathe a larger volume of air than adults, relative to their body mass. Among children, air pollution is linked to a wide array of adverse health impacts, including preterm birth, infant mortality, asthma, respiratory illness, and mental health issues. Higher exposure to air pollution among children is also tied to reduced cognitive

[60] Moda, Haruna M., Walter Leal Filho, and Aprajita Minhas. "Impacts of climate change on outdoor workers and their safety: some research priorities." *International journal of environmental research and public health* 16.18 (2019): 3458.
[61] Applebaum, Katie M., et al. "An overview of occupational risks from climate change." *Current environmental health reports* 3 (2016): 13-22.
[62] MacMurdo, Maeve G., et al. "Ambient air pollution exposure among individuals experiencing unsheltered homelessness." *Environmental Health Perspectives* 130.2 (2022): 027701.

function, lower test scores, impaired IQ, and lower lifetime earnings.[63] Wildfire smoke is particularly dangerous for children; researchers have concluded that it is approximately 10 times more harmful for the respiratory health of children than $PM_{2.5}$ from other sources.[64]

Community Systems Vulnerable to Poor Air Quality

Based upon the results of the survey and feedback from focus groups and public engagement sessions, Clevelanders believe the community systems most vulnerable to poor air quality are public health and safety, ecosystems/environmental health, and community/cultural systems. Northeast Ohio bears a considerable health burden from air pollution, and poor air quality days, like what Cleveland experienced on June 28-29, 2023, further burdens public health infrastructure. One survey respondent stated that “I get headaches sometimes that [lasts] weeks at a time and then one day I looked at the air quality and it was terrible and then a couple days later when the air quality was better, my headache was gone.” Emergency room for respiratory illnesses can double in the days following exposure to wildfire smoke.[65] Prolonged episodes may place a serious strain public health systems; one study estimates that a seven-day pollution event could overwhelm intensive care units.[66] Air pollution is likewise harmful for ecosystem health. Plants and animals suffer from air pollution. According to one survey respondent, “Wildlife is burdened by toxic pollutants coming from the air, soil, or the water ecosystem and, in this way, animals can develop health problems when exposed to high levels of pollutants.” Finally, serious air pollution events can negatively affect community and cultural systems in Cleveland. During June 2023, the City of Cleveland closed pools and playgrounds, suspended outdoor meal programs, and canceled youth sports events due to severe air pollution.[67]

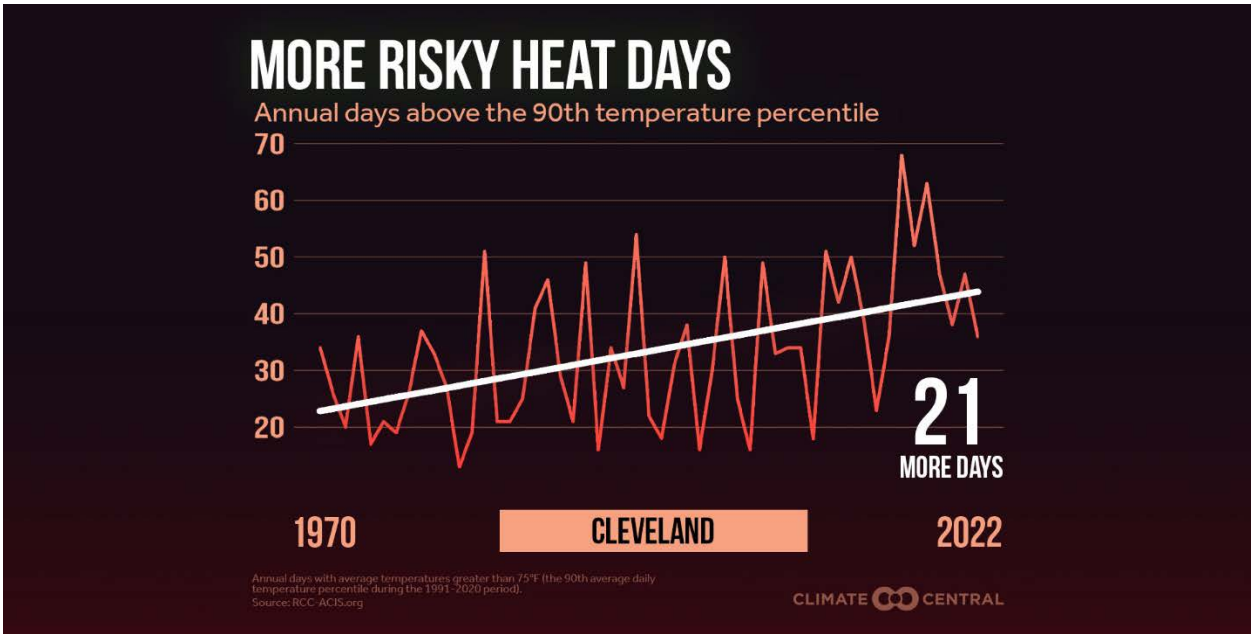
[63] Wang, Pan, et al. "Socioeconomic disparities and sexual dimorphism in neurotoxic effects of ambient fine particles on youth IQ: a longitudinal analysis." *PLoS One* 12.12 (2017): e0188731.
[64] Aguilera, Rosana, et al. "Fine particles in wildfire smoke and pediatric respiratory health in California." Pediatrics 147.4 (2021). Lu, Wenxin, Daniel A. Hackman, and Joel Schwartz. "Ambient air pollution associated with lower academic achievement among US children: a nationwide panel study of school districts." *Environmental epidemiology* 5.6 (2021): e174. Isen, Adam, Maya Rossin-Slater, and W. Reed Walker. "Every breath you take—every dollar you'll make: The long-term consequences of the clean air act of 1970." *Journal of Political Economy* 125.3 (2017): 848-902.
[65] Heft-Neal, Sam, et al. "Emergency department visits respond nonlinearly to wildfire smoke." *Proceedings of the National Academy of Sciences* 120.39 (2023): e2302409120.A
[66] Sorensen, Cecilia, et al. "Associations between wildfire-related PM2. 5 and intensive care unit admissions in the United States, 2006–2015." *GeoHealth* 5.5 (2021): e2021GH000385.
[67] City of Cleveland, “Cleveland Experiencing High Levels of Air Pollution,” June 28, 2023, https://mayor.clevelandohio.gov/cleveland-experiencing-high-levels-air-pollution, accessed March 31, 2024.

Extreme Heat

Past and Current Impacts of Extreme Heat

Extreme heat is perhaps the most apparent effect of climate change. Heat is already deadlier than all other disasters combined in the U.S., and climate change is making this crisis worse.[68] Cleveland's location along Lake Erie has historically buffered it from some of the worst impacts of extreme heat. Risk Factor ranks Cleveland as a moderate heat risk, with a cumulative score of 2.94 out of 10.[69] In Cleveland, hot days are days on which the high temperature reaches or exceeds 90ºF. Over the past 50 years (1974-2023), Cleveland experienced an average of 7.8 hot days per year. This number increased in recent years; since 2010, there have been an average of 10.5 hot days annually. Extremely hot days (95ºF or higher) are even rarer. Since 1974, Cleveland has experienced 55 days at or above 95ºF, an average of just 1.1 days per year. This number has increased slightly in recent years, reaching 1.36 days per year since 2010.[70] Record high temperatures have also become more common in recent years. Cleveland registered more daily record high (59) and monthly record high (four) temperatures during the 2010s than any other decade.[71]

Figure 14: Number of Days above the 90th Temperature Percentile (1970-2022)



Source: Climate Central, "Local Risky Heat Days."

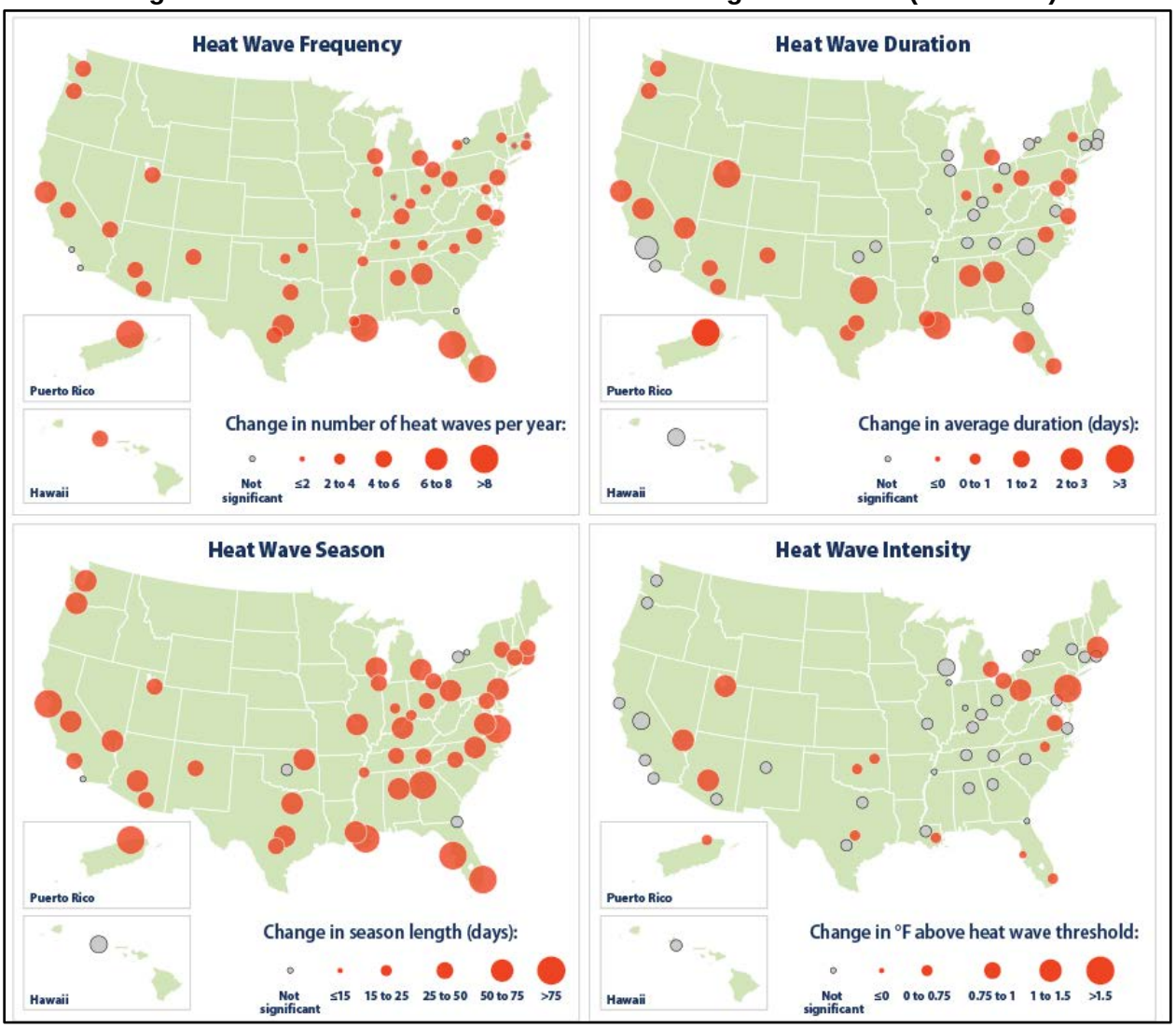
[68] USGCRP, "U.S. Climate Resilience Toolkit: Extreme Heat," July 27, 2022, https://toolkit.climate.gov/topics/human-health/extreme-heat, accessed March 31, 2024.
[69] First Street Foundation, "Heat Factor: Cleveland," https://riskfactor.com/city/cleveland-oh/3916000_fsid/heat, accessed March 31, 2024.
[7070] Data from Midwestern Regional Climate Center (MRCC) cli-MATE tool, https://mrcc.purdue.edu/CLIMATE/, accessed March 31, 2024.
[71] National Weather Service (NWS), "Cleveland Daily Records," https://www.weather.gov/cle/CLERecords, accessed March 31, 2024.

While these hot days are dangerous, Cleveland's temperate climate ensures that residents may experience adverse health effects at lower temperatures. Evidence suggests that the minimum mortality threshold (MMT), which is the point at which the risk of temperature-related mortality is lowest, is approximately the 90th percentile in Cleveland. In other words, once conditions cross this MMT, temperature-related mortality rates increase.[72] In Cleveland, the number of days above the 90th temperature percentile have increased significantly over the past several decades. From 1970-2022, the average number of "risky heat days" increased from approximately 22 to more than 43 per year.[73]

While individual hot days are harmful for human health, the risk increases when people experience consecutive hot days. Heat waves, which the National Weather Service (NWS) defines as a period of abnormally hot weather lasting two or more days, compound these health risks.[74] According to U.S. EPA data, the frequency, duration, and intensity of heat waves have all increased in Cleveland from 1961-2021.[75] During that period, the number of heat waves increased by 5.4 per year, and these heat waves are lasting, on average, 0.7 days longer. The average temperatures of these heat waves have increased by 0.85ºF, which is the ninth largest increase among U.S. cities. Cleveland's heat wave season (i.e. the period in which it can experience heat wave events) has also increased by 48 days. According to a recent study, a 5-day heatwave, combined with a citywide loss of electrical power, would more than double the rate of heat-related mortality in Detroit, a city with a climate and socioeconomic profile similar to Cleveland.[76]

[72] Tobías, Aurelio, et al. "Geographical variations of the minimum mortality temperature at a global scale: a multicountry study." *Environmental epidemiology* 5.5 (2021).
[73] Climate Central, 2023, "More Risky Heat Days in 232 U.S. Locations," https://www.climatecentral.org/climate-matters/more-risky-heat-days-in-232-us-locations, accessed March 31, 2024.
[74] NWS, "Glossary: Heat Wave," https://forecast.weather.gov/glossary.php?word=heat%20wave, accessed March 31, 2024.
[75] U.S. EPA, 2022, "Climate Change Indicators: Heat Waves," https://www.epa.gov/climate-indicators/climate-change-indicators-heat-waves, accessed March 31, 2024.
[76] Stone Jr, Brian, et al. "How blackouts during heat waves amplify mortality and morbidity risk." *Environmental Science & Technology* 57.22 (2023): 8245-8255.

Figure 15: Heat Wave Characteristics in 50 Large U.S. Cities (1961-2021)

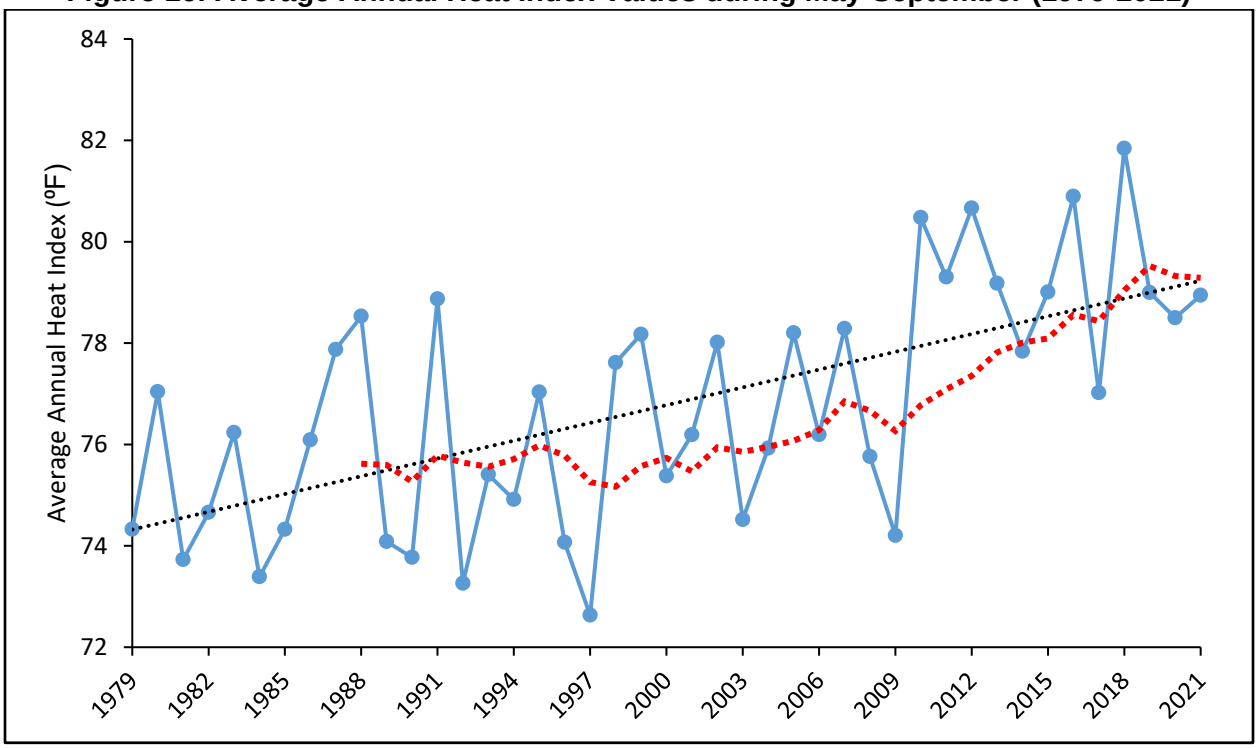


Source: U.S. EPA, "Climate Change Indicators: Heat Waves."

Higher humidity can compound the risks of extreme heat. The heat index, which records what the ambient temperature feels like to the human body when accounting for relative humidity, accounts for this effect.[77] Over the past few decades, heat indices have also been rising in Cleveland. From 1979-1988, the average daily heat index from May to September was 75.6ºF in Cleveland. By 2021, this 10-year rolling average had increased by 4.9% to 79.3ºF.[78] Figure 16, below, charts the increase in annual average heat indices over this period. The dashed black line displays the trend, while the dashed red line shows the moving 10-year average.

[77] NWS, "What is the heat index," https://www.weather.gov/ama/heatindex, accessed March 31, 2024.
[78] Data from Centers for Disease Control and Prevention (CDC), "National Environmental Public Health Tracking Network, https://ephtracking.cdc.gov/DataExplorer/?query=58faf4cf-eeda-4921-8dd9-a3b36532b2f3, accessed March 31, 2024.

Figure 16: Average Annual Heat Index Values during May-September (1979-2021)



Source: CDC, "National Environmental Public Health Tracking Network."

Future Impacts of Extreme Heat

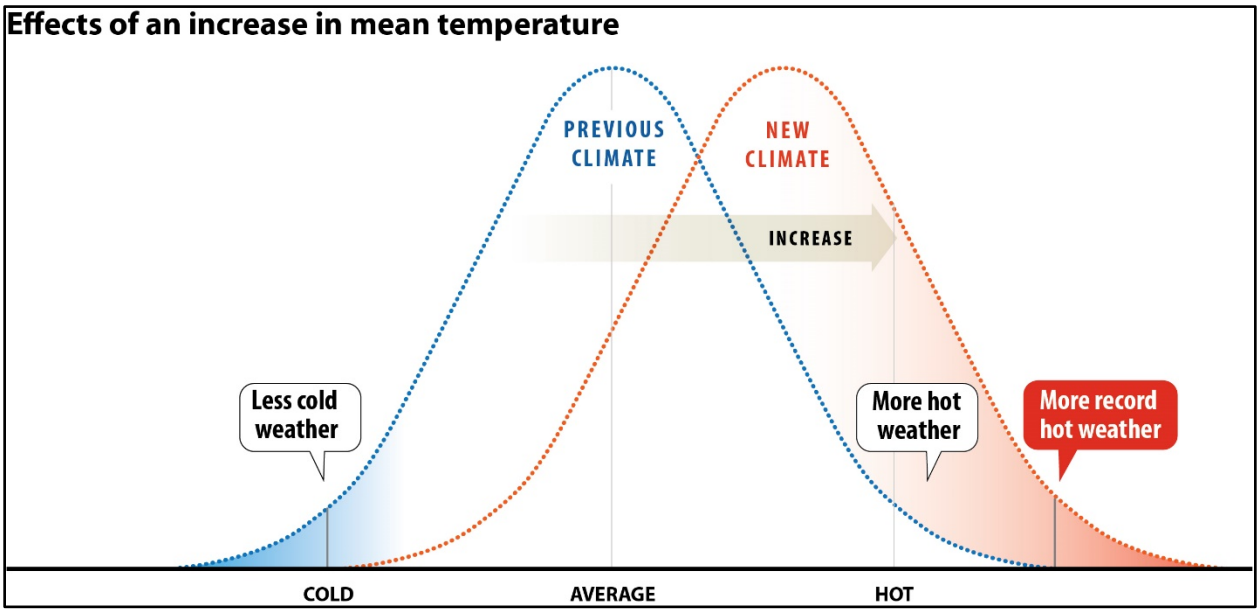
The impact of extreme heat on Cleveland will only become more apparent in the coming decades because of climate change. Under low and high warming scenarios, average daily high temperatures in Cleveland increase by 5.3ºF and 6.7ºF, respectively, by 2050. Looking out to 2100, the increase is even more apparent. Average daily high temperatures are forecast to jump by 6.8ºF and 11.8ºF for low and high warming, respectively. Figure 17 displays this change in average daily maximum temperatures.

Figure 17: Change in Average Daily Maximum Temperatures for Cleveland (1950-2100)

Source: NEMAC, "The Climate Explorer."

While this increase in average daily temperatures is considerable, averages can obscure dramatic changes in extremes. As Figure 18 shows, even small shifts in average temperatures can cause large increases in extremes. Thus, Cleveland will see an increase in the number of days with extremely high temperatures even if average temperatures do not rise as much as the high end of the RCP8.5 projections.

Figure 18: Small Shifts in Average Temperatures Drive Increases in Record Heat

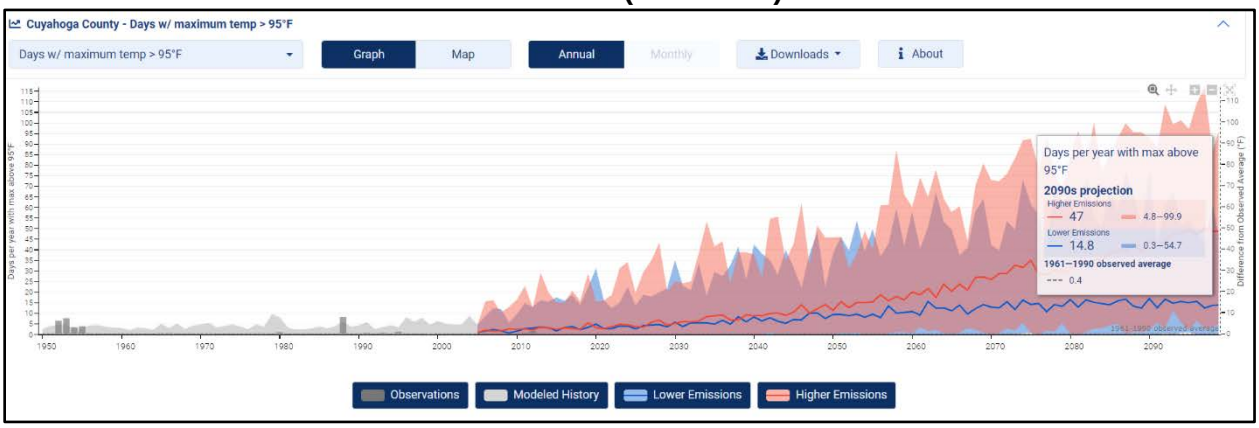


Source: University Corporation for Atmospheric Research (UCAR), "A Tail of Record Heat."

By 2050, the number of 90ºF days is projected to increase to 27 under RCP4.5 and 34 under RCP8.5.[79] This number may increase again to 41-82 days per year by 2100. The number of extreme heat days (days above 95ºF) will also increase from just one per year currently to 8-11 by 2050 and 15-47 per year by 2100. Figure 14, below, shows this projected change. By the end of the century, Cleveland could experience more days with temperatures above 100ºF each year (4-22, depending on scenario) than it has experienced in its recorded history (seven).[80] Perhaps more concerning, from a public health perspective, is the projected increase in the number of very warm nights. The human body needs nighttime temperatures to drop below 75ºF in order to get quality sleep and remain healthy. When temperatures remain above this level throughout the day, it compounds the health impacts of extreme heat. Since recordkeeping began in 1883, Cleveland has only experienced two days where low temperatures do not drop below 80ºF.[81] Under a high warming scenario, this could happen 10 times per year by 2100.

[79] Data from NEMAC, "The Climate Explorer."
[80] Ibid.
[81] NWS, "Cleveland Daily Records."

Figure 19: Change in Number of Days with Maximum Temperatures above 95ºF in Cleveland (1950-2100)



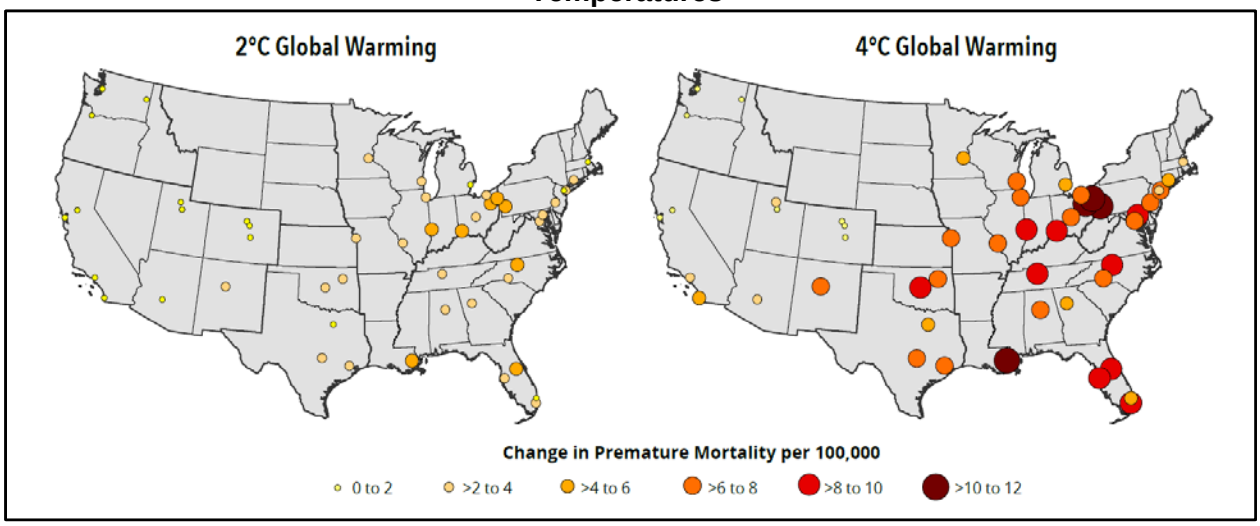
Source: NEMAC, "The Climate Explorer."

The impact of this increase in extreme heat on public health and quality of life will be significant. Because Cleveland's existing climate has largely shielded it from extreme heat of this nature, the city is not well equipped to adapt to these changes. Nearly a quarter of households area lack central air conditioning.[82] In a recent study, U.S. EPA evaluated the projected increase in heat-related mortality under low and high warming scenarios. In RCP4.5, where average global temperatures rise by approximately 2ºC, the heat-related mortality rate in the Cleveland metropolitan area is projected to rise by 670%. Under RCP8.5, the heat-related mortality rate could climb 17-fold.[83] Consequently, under low and high warming scenarios, Cleveland may see an additional 13 to 32 heat-related deaths per year, respectively, by the end of the century.[84] The study looking at the impact of heat waves on Detroit bears this out; by 2100, a 5-day heat wave combined with the loss of power would increase heat-related mortality in the city by 281%.[85]

As part its public engagement efforts, the City of Cleveland asked people to rank the impact of extreme heat on the City. On average, respondents gave extreme heat an average rating of 2.3 for likelihood and 2.3 for consequence. Extreme heat received a total risk score of 5.5, making it the second top scoring climate hazard for Cleveland.

[82] U.S. Census Bureau, "2019 Cleveland — Heating, Air Conditioning, and Appliances — All Occupied Units," https://census.gov/programs-surveys/ahs/data/interactive/ahstablecreator.html?s_areas=17460&s_year=2019&s_tablename=TABLE3&s_bygroup1=1&s_bygroup2=1&s_filtergroup1=1&s_filtergroup2=1, accessed March 31, 2024.
[83] U.S. EPA, *Climate Change and Social Vulnerability.*
[84] Ibid.
[85] Stone Jr., et al.

Figure 20: Projected Increase in Annual Premature Mortality Rates due to Extreme Temperatures



Source: U.S. EPA, *Climate Change and Social Vulnerability in the United States.*

Populations Vulnerable to Extreme Heat

Extreme heat will affect everyone in Cleveland in the coming decades, but these impacts will not be equitable. In the survey and engagement sessions, the City of Cleveland asked respondents to identify the three groups most vulnerable to extreme heat. Based on this feedback, the three populations most vulnerable to extreme heat in Cleveland are outdoor workers, people experiencing homelessness, and people living with medical conditions and disabilities. Because they spend large amounts of time outside and perform vigorous physical activities, outdoor workers are more likely to suffer heat-related health impacts.[86] Extreme heat also reduces the productivity of workers exposed to the hazard. According to U.S. EPA, each climate-exposed worker in Cleveland will lose an average 7.8 and 27.8 hours of work per year under low and high warming scenarios, respectively.[87] The impacts on worker productivity will be greatest in neighborhoods on the West Side of Cleveland. Of the 60 Census tracts where workers would lose at least 30 hours of work per year in a high warming scenario, all but two are located in West Side neighborhoods.[88] Not all outdoor workers will be able to reduce their productivity to cope with higher temperatures, however. Lower income workers and those with little job security, in particular, may choose to continue working on extreme heat days. This outcome places their health at risk and increase the odds of suffering work-related injuries.[89]

Similarly, people experiencing homelessness are highly vulnerable to extreme heat, as they are exposed directly to temperature extremes and may have important heat risk factors that increase the likelihood of suffering serious health impacts. “Risk factors for death during heat

[86] USGCRP, *The Impacts of Climate Change on Human Health*.
[87] U.S. EPA, *Climate Change and Social Vulnerability.*
[88] Ibid.
[89] Ibid., Constible, Juanita, et al, 2020, *On the frontlines: climate change threatens the health of America’s workers,* New York City: Natural Resources Defense Council, https://www.nrdc.org/sites/default/files/front-lines-climate-change-threatens-workers-report.pdf, accessed March 31, 2024.

waves include cardiovascular disease, pulmonary disease, advanced age, living alone, being socially isolated, not using air conditioning, alcoholism, using tranquilizers, and cognitive impairment. These are all characteristics that are more common amongst homeless individuals. Furthermore, up to 91% of homeless populations in the US live in urban or suburban areas, where they are at increased risk from heat waves due to the heat island effect."[90]

Many of these risk factors for heat-related morbidity and mortality also apply to people living with medical conditions and disabilities. Research demonstrates that people with an array of health conditions, including cardiovascular illnesses, dementia, diabetes, neurological disorders, psychiatric illnesses, and renal disease, are more likely to suffer health effects from extreme heat.[91] According to the *Fifth National Climate Assessment* (NCA5), "during periods of higher ambient temperatures and heatwaves, persons with physical and mental disabilities experience adverse health impacts, increased emergency room visits, and higher rates of mortality; cooling measures may be physically or financially inaccessible."[92] Pregnant people are also uniquely vulnerable, as research ties extreme heat to elevated risks of preterm birth, low birthweight, stillbirth, and infant mortality. These risks were particularly high for Black mothers.[93] Given that Cleveland already experiences high rates of infant and maternal mortality, particularly among Black Clevelanders, climate change presents a severe threat to this population.

Community Systems Vulnerable to Extreme Heat

Clevelanders who took part in the survey and engagement sessions indicated that the community systems most vulnerable to extreme heat are ecosystems/environmental health, public health and safety, and food and agriculture. One survey respondent connected the impacts of extreme heat on these systems, stating, "I simply am unable to go outside and walk in the heat or do anything else outside. The humidity was horrible this past summer…I do wonder what happens to plants, the homeless and animals." Another respondent linked the vulnerability of outdoor workers to ecosystem health, writing, "I work in the urban forestry sector so I have had to extend watering season to accommodate for drought (2021/2022), shorten work days due to heat and then accommodate later." Extreme heat and drought can take a toll on ecosystems. During the severe 2011 drought in Texas, more than 300 million trees, including 5.6 million urban shade trees, died due to environmental stress.[94] Heat also stresses public health systems, as people simultaneously seek emergency care for heat-related illnesses and postpone routine healthcare and other essential activities to avoid heat. As one survey respondent wrote, "In the extreme heat or cold I have been unable to make it to doctors and to the grocery store." Extreme heat compromises food security for Cleveland's residents by driving

[90] Ramin, Brodie, and Tomislav Svoboda. "Health of the homeless and climate change." *Journal of Urban Health* 86 (2009): 655-656.
[91] USGCRP, *The Impacts of Climate Change on Human Health*, 222.
[92] Hayden, M.H., et al, 2023, "Ch. 15. Human health," in *Fifth National Climate Assessment*. Crimmins, A.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, B.C. Stewart, and T.K. Maycock, Eds. Washington, DC: USGCRP, https://doi.org/10.7930/NCA5.2023.CH15, accessed March 31, 2024.
[93] Bekkar, Bruce, et al. "Association of air pollution and heat exposure with preterm birth, low birth weight, and stillbirth in the US: a systematic review." *JAMA network open* 3.6 (2020): e208243-e208243.
[94] Texas A&M Forest Service, 2012, "Texas A&M Forest Service Survey Shows 301 Million Trees Killed By Drought," https://tfsweb.tamu.edu/TexasDrought-RuralAreas2011/, accessed March 31, 2024.

down crop yields around the world, which causes inflation in food prices.[95] Additionally, high temperatures can affect food safety and may reduce the nutrient content of certain foods. This outcome disproportionately affects low-income households and communities of color, who spend higher shares of their income on food and have limited access to fresh produce. More than half of Clevelanders live in food apartheid, meaning they live more than a half-mile walk from the nearest supermarket.[96]

Heavy Precipitation & Flooding and Severe Summer Storms

While heavy precipitation and flooding and severe summer storms are distinct climate hazards that the City of Cleveland treated separately in its CRVA engagement efforts, there are strong connections between the two hazards. Both involve heavy rainfall events, and both can involve flooding. Furthermore, respondents gave both hazards nearly identical risk scores and identified the same three vulnerable population groups and vulnerable community assets and systems for each hazard. As a result, this CRVA addresses these two hazards together in this section.

Past and Current Impacts of Heavy Precipitation & Flooding and Severe Summer Storms

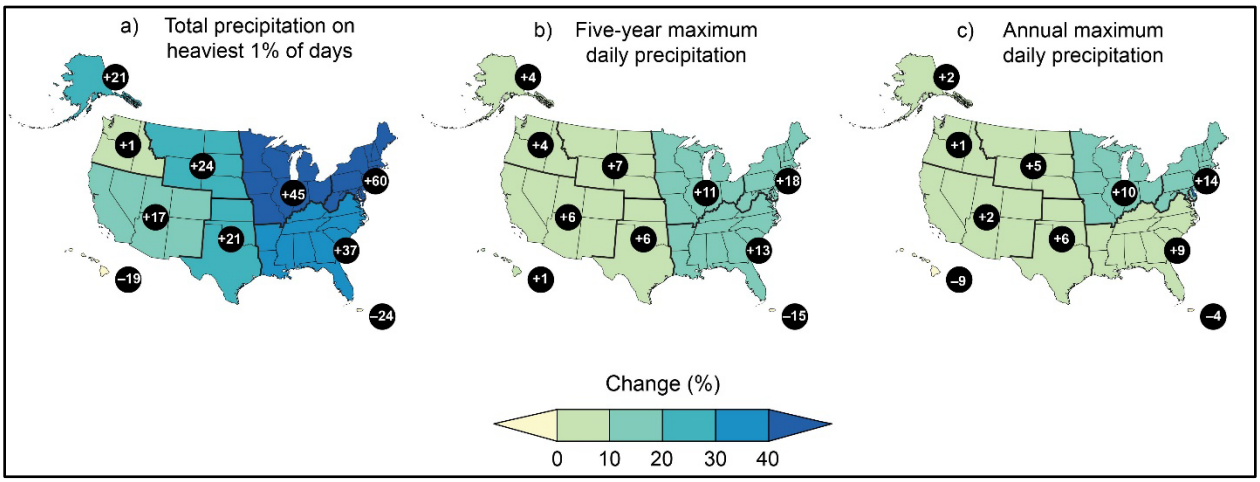
Flooding on Martin Luther King, Jr. Drive on Labor Day 2020. Source: FOX 8 News.

According to the United Nations, “Climate change is primarily a water crisis. We feel its impacts through worsening floods, rising sea levels, shrinking ice fields, wildfires and droughts.”[97] Given Cleveland’s climate and location along Lake Erie, climate change will make itself felt through an excess amount of water, which can overwhelm infrastructure, flood homes, damage property, and threaten public safety. On average, the atmosphere can hold 7% more moisture for every 1ºC of warming, which enables more intense rainfall.[98] Since 1950, annual precipitation in

[95] Faccia, Donata and Parker, Miles and Stracca, Livio, 2021, “Feeling the Heat: Extreme Temperatures and Price Stability,” *ECB Working Paper No. 2021/2626*, http://dx.doi.org/10.2139/ssrn.3981219, accessed March 31, 2024.
[96] Cuyahoga County Planning Commission and Cuyahoga County Board of Health, 2018, *Cuyahoga County Supermarket Assessment 2018 Inventory Update*, Cleveland: Cuyahoga County, https://s3.countyplanning.us/wp-content/uploads/2019/03/Cuyahoga-County-Supermarket-Assessment-2018-Inventory-Update-_FINAL-REPORT-030819.pdf, accessed March 31, 2024.
[97] UN-Water, “Water and Climate Change,” https://www.unwater.org/water-facts/water-and-climate-change, accessed March 31, 2024.
[98] Adam, David. "What a 190-year-old equation says about rainstorms in a changing climate." *Proceedings of the Nationa3443l Academy of Sciences* 120.14 (2023): e2304077120.

Cleveland has increased by nearly one-third (10.4 inches). The largest seasonal changes have occurred during fall and summer, which have seen increases of 53.3% and 30.9%, respectively.[99] This additional precipitation is increasingly falling during heavy storms. Since the 1950s, the amount of rain falling during the heaviest 1% of storms has increased by 45% in the Great Lakes region.[100] Locally, the number of days with more than one inch of precipitation has increased by 1.42 days per decade from 1981 to 2023.[101] Additionally, of the 12 days with at least three inches of rainfall in Cleveland's recorded history, seven have occurred since 2005.[102]

Figure 21: Observed Changes in the Frequency & Severity of Heavy Precipitation Events



Source: USGCRP, *Fifth National Climate Assessment.*

Flash floods, which are heavy or excessive rainfall events over a short period of time that leads to runoff and flooding within minutes or hours, appear to have become more common in Cleveland in recent decades. According to Flood Factor, Cleveland is a major flood risk, as one in every six properties that has greater than a 26% chance of being severely affected by flooding in the next 30 years.[103] Critical infrastructure, such as airports, hospitals, fire stations, and wastewater treatment facilities, are at an even higher risk. From 2013 to 2022, Cleveland experienced four flood events that caused $270,000 in total damages.[104] Additionally, due to climate change and development patterns, flood risk has increased in the Cuyahoga River

[99] GLISA, "Great Lakes Climatologies: Cleveland," https://glisa.umich.edu/station/cleveland/, accessed March 31, 2024.
[100] Marvel, K., et al, 2023, "Ch. 2. Climate trends." In *Fifth National Climate Assessment*. Crimmins, A.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, B.C. Stewart, and T.K. Maycock, Eds, Washington, DC: USGCRP. https://doi.org/10.7930/NCA5.2023.CH2, accessed March 31, 2024.
[101] Romita Grocholski, Krista, et al, 2022, Climate Hazard and Mitigation Planning (CHaMP) Tool: Background and Guidance for Users. Santa Monica, CA: RAND Corporation, https://www.rand.org/pubs/tools/TLA386-9.html, accessed March 31, 2024.
[102] Data from Midwestern Regional Climate Center (MRCC) cli-MATE tool, https://mrcc.purdue.edu/CLIMATE/, accessed March 31, 2024.
[103] First Street Foundation, "Flood Factor: Cleveland https://riskfactor.com/city/cleveland-oh/3916000_fsid/flood, accessed March 31, 2024.
[104] Data from NOAA NCEI, "Storm Events Database," https://www.ncdc.noaa.gov/stormevents/, accessed March 31, 2024.

watershed. The amount of water in the River's annual flood event increased by 40% from 1922-1975 to 1976-2018.[105]

Severe summer storms have also taken a toll on Cleveland. From 2013-2022, Cleveland experienced 25 episodes of damaging winds. These storms caused a total of $2.2 million in damages. The city experienced another 13 episodes of thunderstorm winds that caused additional damages. While Cleveland experiences an array of severe storms, the historic risk of tornadoes has been very low. From 1950-2023, 17 tornadoes touched down in Cuyahoga County. Just five of these affected Cleveland.[106] Most recently, an EF1 tornado touched down on the East Side over the evening of August 24-25, 2023.

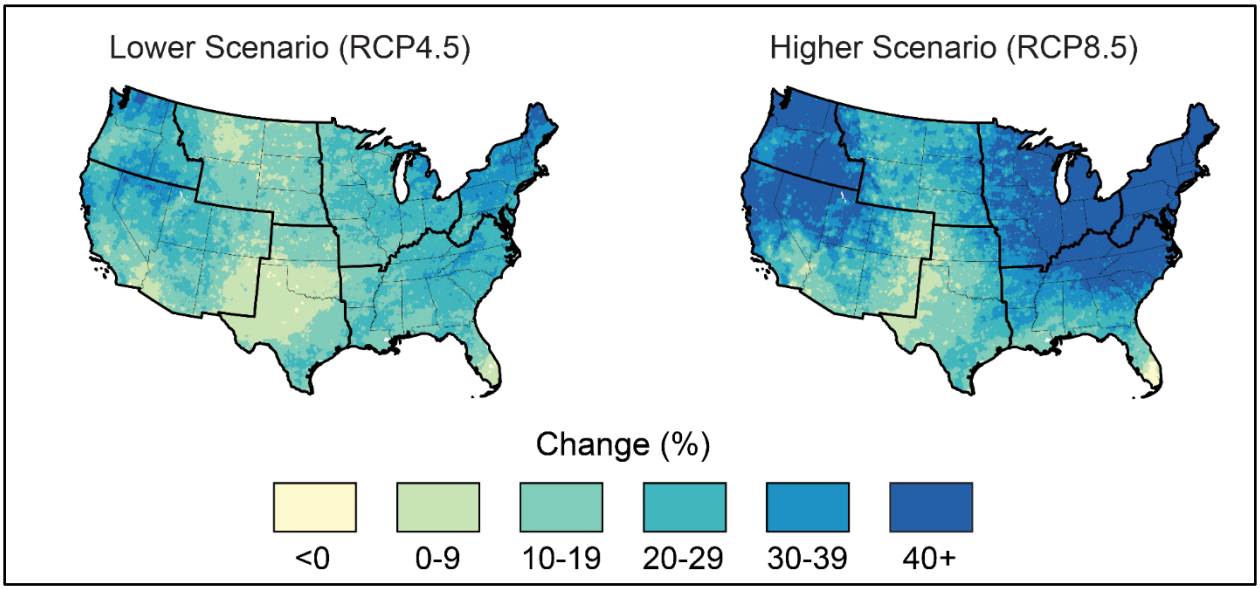
Future Impacts of Heavy Precipitation & Flooding and Severe Summer Storms

Climate change will further exacerbate heavy precipitation and flooding and severe summer storms in Cleveland. Annual precipitation will increase from 52.2 inches per year to 60.3 inches and 61.6 inches in 2050 under RCP4.5 and RCP8.5, respectively. By 2100, precipitation could spike to 86.6 inches under a high warming scenario. Heavy rainfall events will also increase further. As Figure 22 illustrates, the share of precipitation falling in the heaviest 1% of events could increase by another 20% under a low warming scenario, and by more than 40% under a high warming scenario.[107] Risk Factor projects that the share of properties at flood risk will increase by 8% through 2050. By this point, 1,132 of 1,899 lane miles of roads in Cleveland are at risk of becoming impassable during a century flood.[108] There may also be a slight increase in average wind speeds, but the projected change is insignificant.

As part of its public engagement efforts, the City of Cleveland asked people to rank the impact of heavy precipitation and flooding and severe summer storms. Respondents gave heavy precipitation and flooding an average rating of 2.3 for likelihood and 2.3 for consequence, for a total risk of 5.2. Sever summer storms received average scores of 2.3 for likelihood, 2.2 for consequence, and 5.1 for total risk.

[105] National Park Service, U.S. Army Corps of Engineers, and U.S. EPA, 2021, *Cuyahoga River Restoration: Boston Mills North Project Introduction and Public Scoping*, https://parkplanning.nps.gov/document.cfm?parkID=121&projectID=89642&documentID=105031, accessed March 31, 2024.
[106] Data from NOAA NCEI, "Storm Events Database," https://www.ncdc.noaa.gov/stormevents/, accessed March 31, 2024
[107] Hayhoe, K., 2018, "Our Changing Climate," in *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)], Washington, DC: USGCRP, https://nca2018.globalchange.gov/chapter/2/, accessed March 31, 2024.
[108] First Street Foundation, "Flood Factor: Cleveland https://riskfactor.com/city/cleveland-oh/3916000_fsid/flood, accessed March 31, 2024.

Figure 22: Projected Changes in Heavy Precipitation Events by 2100



Source: USGCRP, *Fourth National Climate Assessment.*

Populations Vulnerable to Heavy Precipitation & Flooding and Severe Summer Storms

Based on feedback from residents and stakeholders, the three most vulnerable population groups to both heavy precipitation and flooding and severe summer storms are people experiencing homelessness, outdoor workers, and people living in low-income and disinvested communities. People experiencing homelessness typically are exposed more to disasters like flooding and severe summer storms. Homeless encampments are often located in marginal areas, which places them in acute risk during extreme weather events. Disaster planning processes frequently exclude homeless populations, which increases their vulnerability due to this marginalization.[109] Furthermore, homeless individuals may have trouble accessing shelters during disaster periods due to increased demand for shelter services, and increased housing demand after disaster events can make it even harder for them to secure stable housing.[110] Outdoor workers similarly face direct risks from storms and flooding, particularly those engaged in emergency response and recovery work. “The inherent dangers of post-storm work—such as downed power lines, falling tree limbs, and falls from ladders and roofs—can be exacerbated by 12- to 18-hour workdays, inadequate health and safety training, a lack of housing, and insufficient access to, or time for, proper meals.”[111] Outdoor workers engaged in other trades can also suffer, as storms may damage businesses and force them to close for extended periods, costing hourly and low-income workers vital earnings at critical times.

[109] Ramin and Svoboda, 657.
[110] Bezgrebelna, Mariya, et al. "Climate change, weather, housing precarity, and homelessness: A systematic review of reviews." *International Journal of Environmental Research and Public Health* 18.11 (2021): 5812.
[111] NRDC, *On The Front Lines*, 14.

Firefighters perform water rescues of stranded drivers on Interstate 90 on August 23, 2024. Source: WKYC-TV.

People living in low-income and disadvantaged communities are also particularly vulnerable, as they tend to live in lower quality housing. These housing units are often in riskier areas due to spatial segregation and redlining. “Generally, rich people tend to take the higher ground, leaving the poor and working class more vulnerable to flooding and environmental pestilence”[112]

Substandard water infrastructure in low-income areas can increase the risk of nuisance flooding and sewer backups, which can further damage housing and expose people to waterborne diseases.[113] Low-income populations may struggle to take precautions in the wake of storms and flood events, as they may lack the resources needed to mitigate risks. In the aftermath of storms and floods, low-income households may struggle to recover, because they are less likely to receive sufficient recovery assistance.[114] Lastly, nature-based infrastructure projects, which are key tools to protect communities from flooding risks, sometimes exclude socially vulnerable groups and increase displacement risks for low-income residents. Cities must be proactive to ensure that the people at greatest risk of climate hazards can benefit from these resilience measures instead of being driven into other communities at risk.[115]

Community Systems Vulnerable to Heavy Precipitation & Flooding and Severe Summer Storms

Respondents to the survey and participants in engagement sessions identified ecosystems/environmental health, food and agriculture, and public health and safety as the most vulnerable community systems for both heavy precipitation and flooding and severe summer storms. As climate change makes flooding and storms more severe, species native to Cleveland will continue to suffer, as they have not evolved to survive these conditions. Evidence suggests that extreme weather events may be beneficial for invasive species in the Great Lakes

[112] Bullard, Robert D. "Differential vulnerabilities: Environmental and economic inequality and government response to unnatural disasters." Social Research: An International Quarterly 75.3 (2008): 757.
[113] USGCRP, *The* Impacts *of Climate Change on Human Health*, 253.
[114] Hersher, Rebecca, and Ryan Kellman. "Why FEMA aid is unavailable to many who need it the most." National Public Radio (NPR), June 29 2021, https://www.npr.org/2021/06/29/1004347023/why-fema-aid-is-unavailable-to-many-who-need-it-the-most, accessed February 15, 2024.
[115] U.S, EPA, *Climate Change and Social Vulnerability in the United States, Appendix 1. Flooding*, Washington, DC: U.S. EPA, 1-4, https://www.epa.gov/system/files/documents/2021-09/appendix-i_inland-flooding.pdf, accessed March 31, 2024.

region, as they often possess traits that make them better equipped to weather these storms.[116] Flooding and storms can also undermine food security in Cleveland. Extreme weather events can harm agriculture, reducing supplies and driving up costs of nutritious foods. Storm-related power outages can cause food to spoil and reduce the supply of perishable foods at local markets. Lastly, floods and storms can affect public health systems negatively. “Health care access and infrastructure can be severely affected by floods, including loss of records, impacts on water supplies and laboratory functions, reduced access to health care, and evacuation, with subsequent consequences for the communities served.”[117] Respondents to the survey reported missing or having to reschedule medical appointments due to severe weather events.

Table 10: Vulnerable Population Groups and Community Systems for Priority Climate Hazards in the City of Cleveland

Climate Hazard	Vulnerable Populations	Vulnerable Community Systems
Poor Air Quality	Outdoor Workers	Public Health
	People Experiencing Homelessness	Ecosystems/Environmental Health
	Children	Community/Cultural
Extreme Heat	Outdoor Workers	Ecosystems/Environmental Health
	People Experiencing Homelessness	Public Health
	People Living with Medical Issues/Disabilities	Food and Agriculture
Heavy Precipitation & Flooding, Severe Summer Storms	People Experiencing Homelessness	Ecosystems/Environmental Health
	Outdoor Workers	Food and Agriculture
	People Living in Low-Income/Disinvested Communities	Public Health

[116] Gu, Shimin, et al. "Meta-analysis reveals less sensitivity of non-native animals than natives to extreme weather worldwide." *Nature Ecology & Evolution* 7.12 (2023): 2004-2027.
[117] Ebi, Kristie L., et al. "Extreme weather and climate change: population health and health system implications." *Annual review of public health* 42.1 (2021): 301.

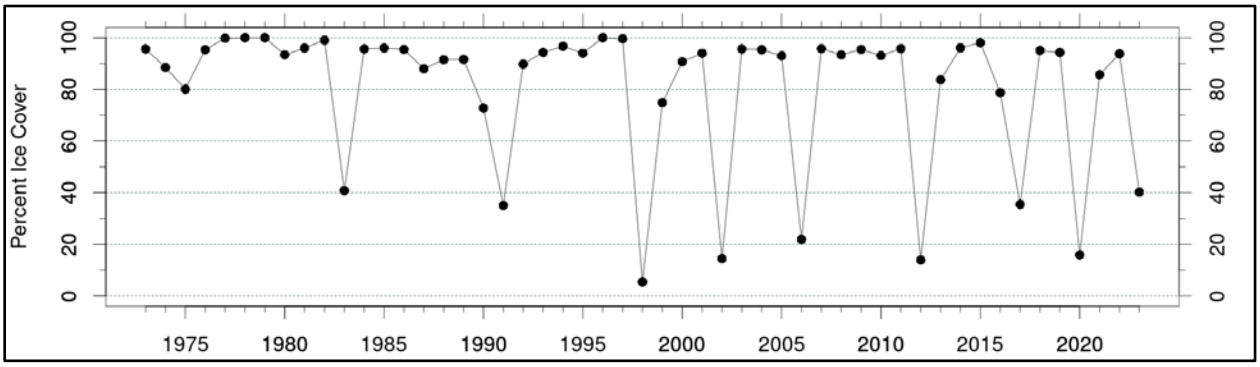
Other Climate Hazards in Cleveland

As discussed in Chapter 2, the City of Cleveland evaluated 10 total climate hazards for this CRVA. The following sections briefly review the remaining six hazards.

Changes to Lake Erie

Climate change is already taking a profound toll on Cleveland's greatest natural resource, Lake Erie. Winter ice cover serves an important ecological purpose for Lake Erie. Among other things, it helps to reduce evaporation, stabilize habitats for fish species that spawn in the fall and winter months, and minimize costal erosion.[118] Over the past 50 years, annual average ice cover on Lake Erie has decreased by 50%. The duration of annual ice cover has also fallen. From 1973-1982, ice covered Lake Erie for 94.7 days per year, on average. By 2020, this rolling 10-year average duration fell to just 69.8 days per year.[119] This continued reduction in ice cover will have significant impacts on Cleveland. Reduced ice cover can increase surface evaporation, cause more lake-effect precipitation, exacerbate coastal erosion, increase summertime temperatures, and contribute to hypoxia episodes.[120]

Figure 23: Annual Maximum Ice Cover on Lake Erie (1973-2023)



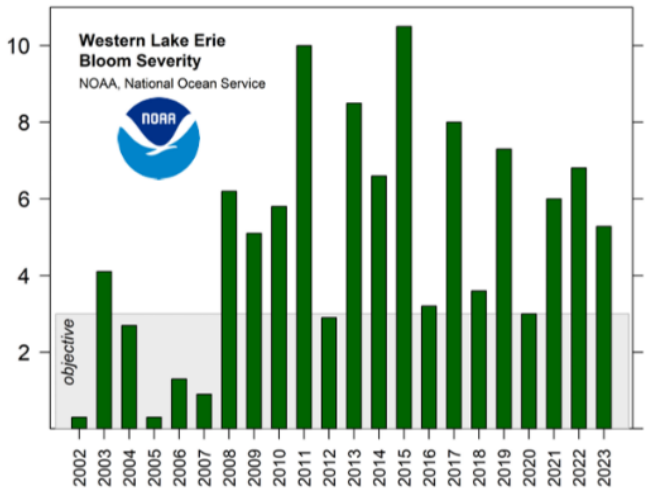
Source: NOAA Great Lakes Environmental Research Laboratory (GLERL), https://www.glerl.noaa.gov/data/ice/#historical.

Climate change is also contributing to the rise in harmful algal blooms (HABs) that have plagued Lake Erie over the past two decades. "Rising carbon dioxide concentrations, warming lake temperatures, a longer stratified-lake season, increasing extreme precipitation, and an abundance of nutrients all combine to increase the risk of harmful algal blooms."[121] NOAA has created an index to chart the intensity of HABs each year. Since 2002, HABs on Lake Erie have exceeded the target intensity of 3.0 on 14 separate occasions. The 10-year rolling average HAB

[118] Wuebbles, Donald, et al, 2019, *An assessment of the impacts of climate change on the Great Lakes*, Chicago: Environmental Law and Policy Center, https://elpc.org/wp-content/uploads/2020/04/2019-ELPCPublication-Great-Lakes-Climate-Change-Report.pdf, accessed March 31, 2024.
[119] Data from NOAA Great Lakes Environmental Research Laboratory (GLERL), 2024, "Historical Ice Cover," https://www.glerl.noaa.gov/data/ice/#historical, accessed March 31, 2024.
[120] Wuebbles, et al, *An assessment of the impacts of climate change on the Great Lakes*.
[121] GLISA, "Algal Blooms," https://glisa.umich.edu/resources-tools/climate-impacts/algal-blooms/, accessed March 31, 2024.

intensity has more than doubled over that span to 5.93 from 2014-2023 from 2.67 from 2001-2010.[122]

Figure 24: Western Lake Erie HAB Severity Index (2002-2023)



Source: NOAA National Centers for Coastal Ocean Science

The worst HAB on record occurred in 2015, when it reached 10.5 out of 10 on the index and covered approximately 300 square miles of Lake Erie. Rising lake temperatures and increased heavy rainfall, which is loading the lake with phosphorus-laden runoff from the Maumee River basin, has contributed to this return of HABs. Research suggests that both the frequency and severity of HABs will increase due to a changing climate, though improved agricultural practices can somewhat offset this rise. Without best practices to reduce nutrient loading, however, the odds of a severe HAB occurring each year will increase to 24% by mid-century.[123]

Based on resident and stakeholder feedback, the three most vulnerable population groups to changes to Lake Erie are children, outdoor workers, and people living in low-income and disadvantaged communities. The most vulnerable community systems are ecosystems/environmental health, public health and safety, and food and agriculture.

Changing Seasonal Conditions

Climate change is significantly altering the seasonal conditions that humans, animals, and plant life have become accustomed to in Cleveland. Since the 1950s, average annual temperatures have increased by 2.6ºF in Cleveland, a rate of warming higher than either the U.S. or the planet.[124] The highest rate of warming has occurred during winter (3.6ºF), followed by spring (2.6ºF). Winters are becoming shorter and milder in Cleveland. The frost-free season has increased by 32 days from 1970 to 2022, and there has been a significant increase in the number of unfrozen days (i.e. days where temperatures do not drop below 32ºF.[125]

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[122] Data from NOAA NCCOS, https://coastalscience.noaa.gov/science-areas/habs/hab-forecasts/lake-erie/

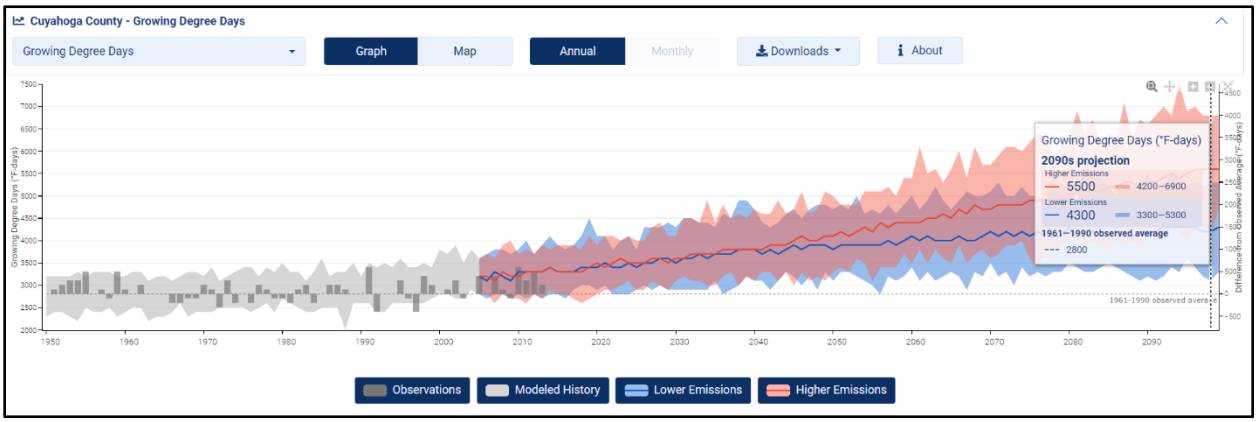
[123] Confesor, Jr., Remegio and Tian Guo, 2019, *Climate change effects on major drivers of harmful algal blooms (HABs): best management practices and HAB severity*, Brussels: Copernicus Climate Change Service, http://dx.doi.org/10.13140/RG.2.2.22041.57447, accessed March 31, 2024.

[124] GLISA, “Great Lakes Climatologies: Cleveland.”

[125] Climate Center, 2023, “Allergy Season: Earlier, Longer, and Worse,” https://www.climatecentral.org/climate-matters/allergy-season-earlier-longer-and-worse-2023. U.S. EPA, 2023, “Climate Change Indicators: Freeze-Thaw Conditions,” https://www.epa.gov/climate-indicators/climate-change-indicators-freeze-thaw-conditions,” accessed March 31, 2024.

The growing season now lasts more than two weeks longer (16.3 days) in Ohio, altering the behaviors of plants and animals in the region.[126] First leaf and first bloom dates occurred 9.5 and 4.1 days earlier, respectively, from 2011 to 2020 than for 1951 to 1960.[127] This also extends the allergy season, causing hardship for Clevelanders who suffer with asthma and allergies.

Figure 25: Change in Number of Growing Degree Days in Cleveland (1950-2100)



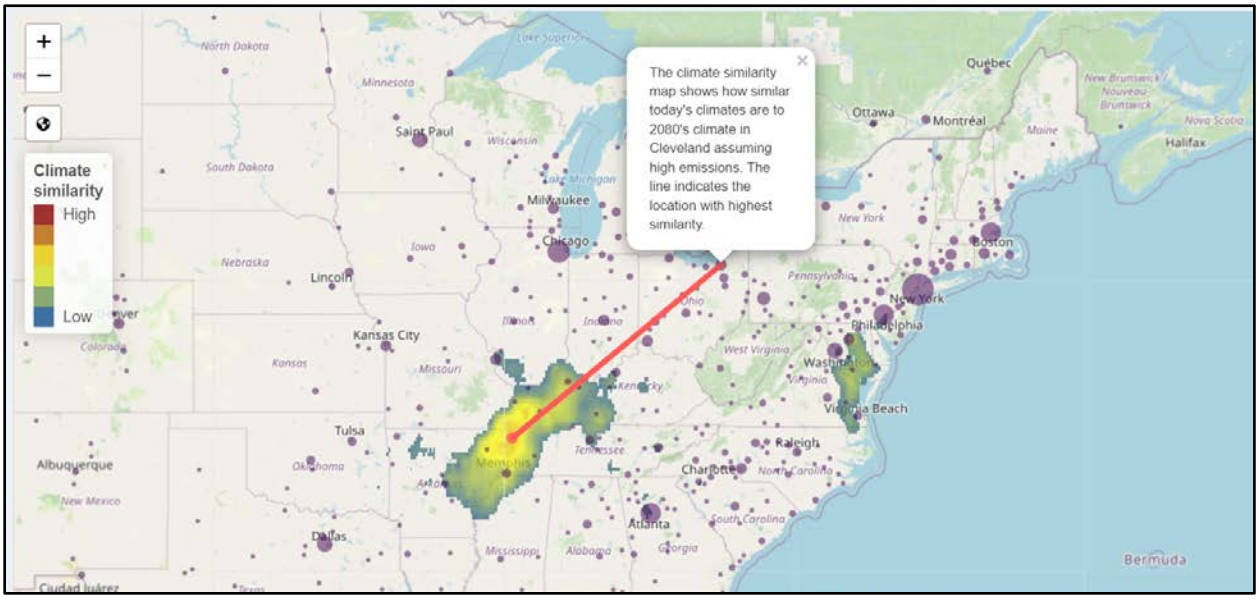
Source: NEMAC, "The Climate Explorer."

Climate change will continue to alter the seasons in Cleveland going forward. Winters will become shorter and milder, as the number of days with temperatures below freezing will fall 21-28% by 2050 and 29-52% by 2100, depending on the scenario. The number of growing degree days (GDD), a statistic used to estimate the length and suitability of seasons for plant growth and insects, will also rise considerably. Under RCP4.5 and RCP8.5, Cleveland will experience 35% and 46% more GDDs by 2050, respectively. The number of GDDs will rise further by 49-91%, by 2100, depending on the warming scenario. Ultimately, Cleveland's climate will shift dramatically. By 2080, summers in Cleveland will be roughly 9ºF warmer, on average, under RCP8.5, making Cleveland's climate more similar to that of Kennett, Missouri, a city some 575 miles to the southwest.[128]

The three most vulnerable population groups to changing seasonal conditions are people experiencing homelessness, outdoor workers, and people living in low-income and disinvested communities. The three most vulnerable community systems are ecosystems/environmental health, food and agriculture, and public health and safety.

[126] U.S. EPA, 2021, "Climate Change Indicators: Length of Growing Season," https://www.epa.gov/climate-indicators/climate-change-indicators-length-growing-season, accessed March 31, 2024.
[127] U.S. EPA, 2021, "Climate Change Indicators: Leaf and Bloom Dates," https://www.epa.gov/climate-indicators/climate-change-indicators-leaf-and-bloom-dates, accessed March 31, 2024.
[128] Fitzpatrick, Matthew C., and Robert R. Dunn. "Contemporary climatic analogs for 540 North American urban areas in the late 21st century." *Nature communications* 10.1 (2019): 1-7.

Figure 26: Climate Similarity Map for Cleveland by 2080s under High Warming Scenario



Source: University of Maryland Center for Environmental Science - Appalachian Lab, "The Future Urban Climates."

Drought

Cuyahoga County experienced significant drought conditions during the 1930s, 1940s, and 1960s, as Figure 27 illustrates. However, this shifted to persistent wet conditions beginning in the 1970s, and this shift became even more pronounced by the early 2000s. The region has experienced a few droughts in recent years. From 2000 to 2022, abnormally dry conditions, the most minor drought category, covered more than half of Cuyahoga County for 64 weeks (5.3% of period). The worst drought occurred during August and September 2001, when severe drought affected up to 96.6% of the county.[129] During May and June 2023, Cleveland experienced its second longest dry period on record, as it registered no measurable precipitation for 21 straight days.[130] While precipitation is projected to increase in Cleveland in the coming decades, the dry periods may also last longer, as a warming atmosphere can hold more moisture before reaching the saturation point. As a result, the number of dry days in Cleveland may increase slightly to 158.9 days under RCP4.5 and 164.2 days under RCP8.5, respectively, up from an historical average of 158.9 days.[131]

The three most vulnerable population groups to drought are people living in low-income and disinvested communities, people experiencing homelessness, and outdoor workers. The three most vulnerable community systems are ecosystems/environmental health, food and agriculture, and public health and safety.

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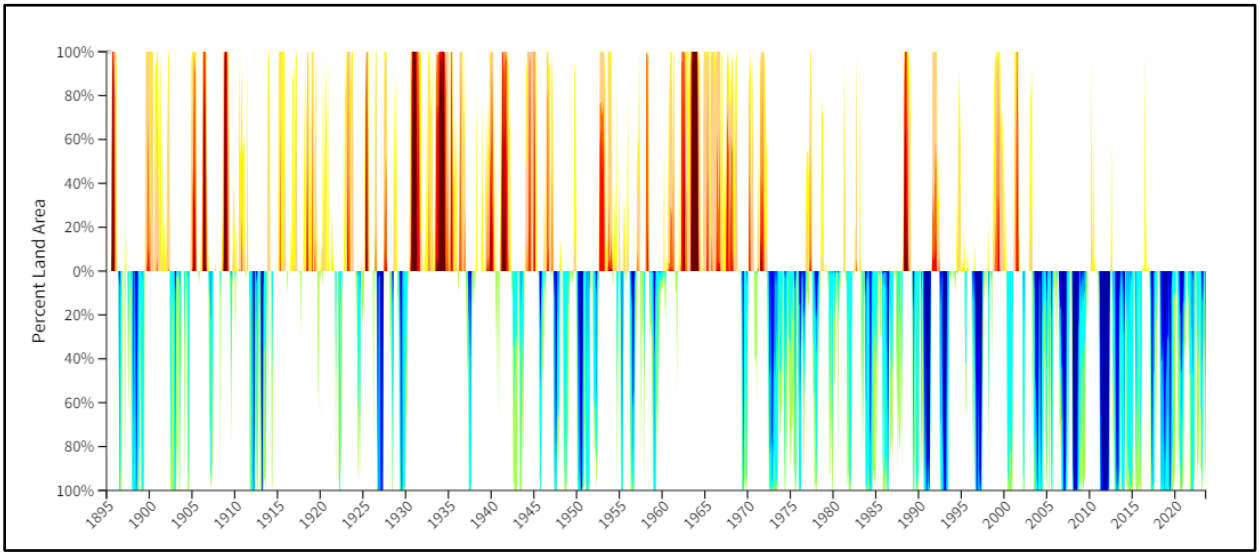
[129] U.S. Department of Agriculture (USDA), "Historical Drought Conditions: Cuyahoga County," https://www.drought.gov/historical-information, accessed March 31, 2024.
[130] Exner, Rich, " When will Northeast Ohio's near-record dry spell end? - Hint: enjoy SaturdaY," Cleveland.com, June 10 2023, https://www.cleveland.com/news/2023/06/when-will-northeast-ohios-near-record-dry-spell-end-hclicliint-enjoy-saturday.html, accessed March 31, 2024.
[131] Data from NEMAC, "The Climate Explorer."

Figure 27: Historical Drought Conditions for Cuyahoga County (1895-2023)



Source: U.S. Department of Agriculture, “Drought.gov.”

Insect Infestation

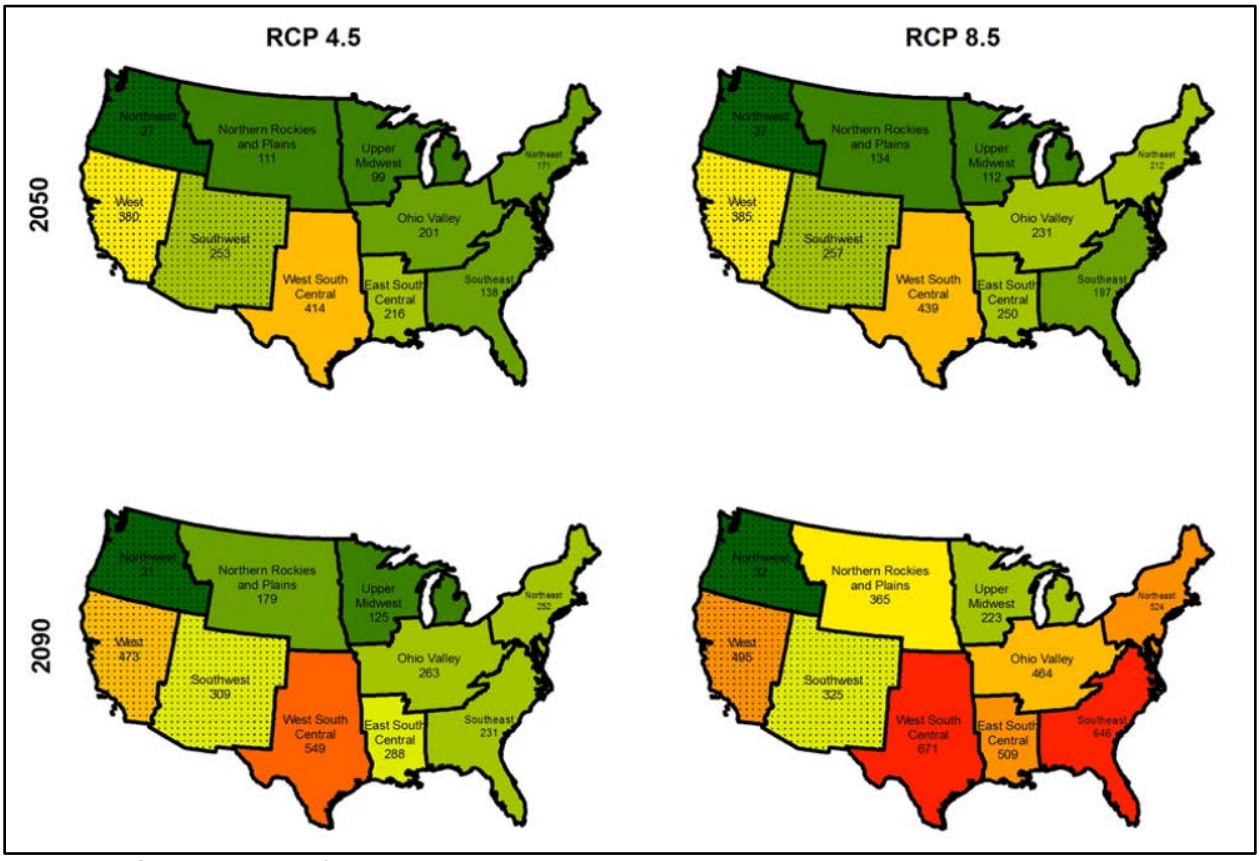
Warming winters and longer growing seasons in Cleveland are creating conditions that are more favorable for harmful insect species. Many destructive insects, such as the emerald ash borer, cannot survive freezing winter temperatures, which acts as a natural check on their ranges. As winters have gotten warmer and the number of unfrozen days has increased, these insect species have proliferated, undermining ecosystem health in Northeast Ohio.[132] Recently, the spotted lanternfly, a highly invasive insect that can harm the viticulture, tree fruit, nursery, and timber industries, has entered Cleveland.[133] The changing climate likely facilitated this expansion of its range. Lastly, disease-carrying insects, including mosquitos, blacklegged ticks, and deer ticks have become more widespread in the region.

As the growing season has lengthened, so has the mosquito season; from 1979 to 2022, the annual number of days suitable for mosquitoes has increased by 27 per year.[134] This may contribute to an increase in the spread of mosquito-borne illnesses, including West Nile, as Figure 28 shows.[135] There has also been a steady increase in the number of cases of Lyme

[132] Angel, J. et al., 2018, “Midwest,” in *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. Washington, DC: USGCRP, 872–940, https://nca2018.globalchange.gov/chapter/21/, accessed March 31, 2024.
[133] Cleveland Metroparks, “Spotted Lanternfly,” https://www.clevelandmetroparks.com/about/conservation/current-issues/spotted-lanternfly-1, accessed March 31, 2024.
[134] Climate Central, 2023, “Mosquito Days,” https://www.climatecentral.org/climate-matters/mosquito-days-2023, accessed March 31, 2024.
[135] Belova, Anna, et al. "Impacts of increasing temperature on the future incidence of West Nile neuroinvasive disease in the United States." *American Journal of Climate Change* 6.01 (2017): 166.

disease in Ohio in recent years.[136] The three most vulnerable population groups to insect infestation are outdoor workers, people living in low-income and disinvested communities, and people experiencing homelessness. The three most vulnerable community systems are ecosystems/environmental health, food and agriculture, and public health and safety.

Figure 28: Projected Change in West Nile Virus Cases under RCP4.5 and RCP8.5



Source: Belova, Anna, et al.

Invasive Plant Species

Changing climatic conditions can combine with other stressors, including development and habitat clearance, to create the conditions for invasive plant species to take hold and proliferate in Northeast Ohio. A number of invasive plants are common already in Cleveland, including garlic mustard, purple loosestrife, Japanese knotweed, and phragmites.[137] As the climate changes, the conditions in which native plant have evolved are shifting; Northeast Ohio has

[136] Ohio Department of Health, "Lyme Disease," https://odh.ohio.gov/know-our-programs/zoonotic-disease-program/diseases/lyme-disease#:~:text=Lyme%20disease%20cases%20are%20increasing,habitats%20preferred%20by%20this%20tick., accessed March 31, 2024.
[137] Cleveland Metroparks, "Invasive Plant Management," https://www.clevelandmetroparks.com/about/conservation/resource-management/invasive-plant-management-1, accessed March 31, 2024.

already moved up to USDA Plant Hardiness Zone 6.[138] Native plant species may struggle to adjust to these new conditions; one study estimates that more than one-third of native tree species will struggle to survive in the region by 2100.[139] Ohio's iconic buckeye species may have to migrate north to Michigan to survive in the coming decades. As native species continue to struggle, invasive species will likely find conditions ripe to expand throughout the region.

The three most vulnerable population groups to invasive plant species are outdoor workers, people living in low-income and disinvested communities, and people experiencing homelessness. The three most vulnerable community systems are ecosystems/environmental health, food and agriculture, and public health and safety.

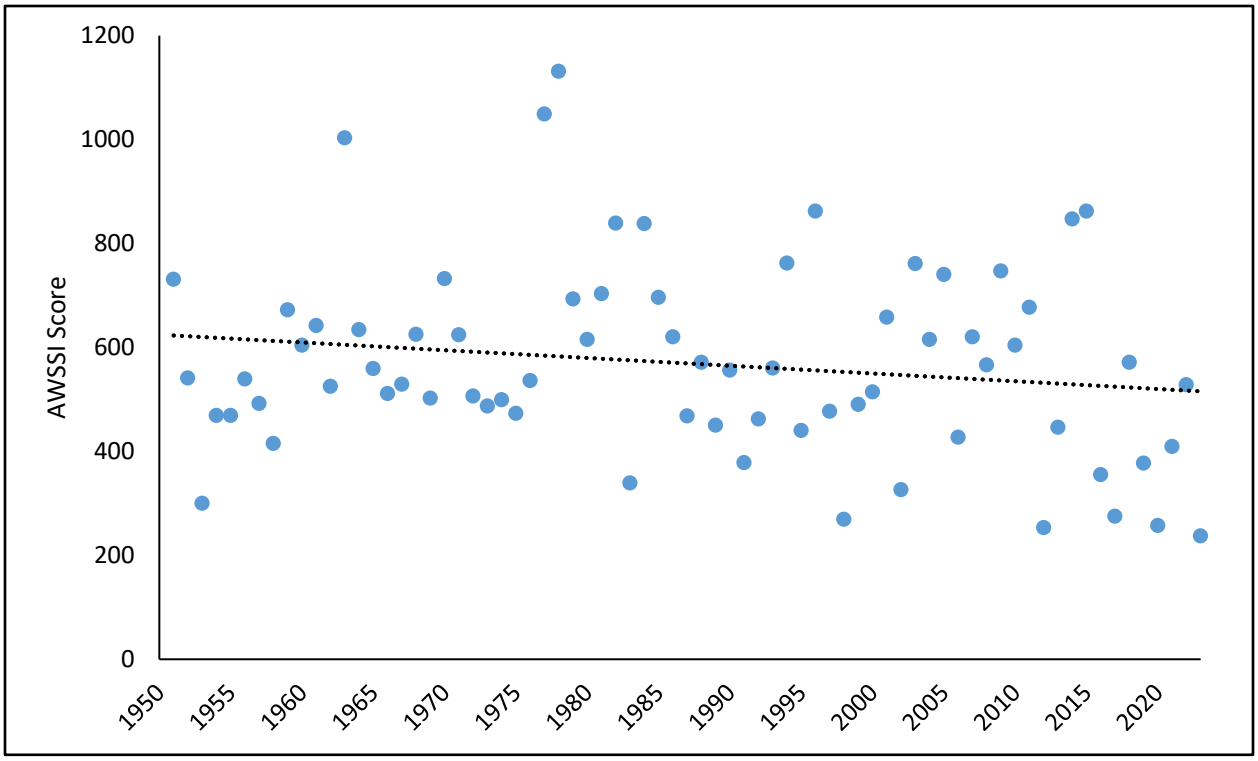
Severe Winter Weather

Severe winter weather, including freezing temperatures and ice and snow, has historically been the most dangerous climate hazard in Cleveland. From 2013 to 2022, the region experienced seven cold weather events that caused property damage, injuries, and deaths. From January 29-31, 2019, a cold front plunged windchills to -31ºF, causing $100,000 in damages and three deaths. During the first half of February 2021, seven people died due to extreme cold temperatures.[140] While each of these events is tragic and costly, they are becoming less common due to climate change. From the 1940s to the 1990s, Cleveland averaged 40.5 daily record low temperatures and 1.8 record monthly low temperatures per decade. There were just 20 and 19 daily record lows during the 2000s and 2010s, respectively, along with just one monthly record low in the 2010s. There were no record monthly low temperatures during the 2000s.[141] Extremely cold days are becoming less common in general; from 1982-2023, the number of days with low temperatures below 0ºF decreased by 0.28 days per decade.[142]

While severe winter weather is still common, winters appear to be getting shorter and milder in Cleveland. The Accumulated Winter Season Severity Index (AWSSI) is a composite statistic that combines temperatures, snowfall, and snow depth to measure objectively the relative severity of winter.[143] As Figure 29 shows, AWSSI scores have decreased, on average, in Cleveland since the 1950s. The AWSSI peaked in winter 1977-1978 and has been decreasing since. It reached a record low in 2022-2023, and four of the five mildest winters have taken place since 2011-2012.

[138] USDA, 2023, "2023 USDA Plant Hardiness Zone Map," https://planthardiness.ars.usda.gov/, accessed March 31, 2024.
[139] Lake Erie Allegheny Partnership for Biodiversity (LEAP), "Changing Climate, Changing Trees," https://www.leapbio.org/biodiversity-plan/climate, accessed March 31, 2024.
[140][140] Data from NOAA NCEI, "Storm Events Database," https://www.ncdc.noaa.gov/stormevents/, accessed March 31, 2024.
[141] NWS, "Cleveland Daily Records."
[142] Data from NOAA CHaMP Tool.
[143] MRCC, "About AWSSI," https://mrcc.purdue.edu/research/about-awssi, accessed March 31, 2024.

Figure 29: AWSSI Scores for Cleveland (1950-1951 to 2022-2023)



Source: MRCC, "AWSSI."

Climate change will accelerate this trend of shorter, milder winters in Cleveland. By 2050, the number of days with high temperatures below the freezing mark will fall by 17 under RCP4.5 and 20 under RCP8.5, respectively, a decrease of 42-51%, compared to the 1981-2010 average.[144] This number will decline by another three to 11 days per year by 2100, a 53% to 80% total reduction under low and high warming scenarios, respectively. Heating degree days (HDDs), a statistic that measures the severity of cold temperatures over the course of a year, are projected to decrease 19% under RCP4.5 and 24% under RCP8.5 by 2050.[145] By the end of the century, HDDs may fall by 25% to 40%. While wintertime temperatures will continue to rise, it remains possible that Cleveland could see an increase in extreme snowfall in the near term. As ice cover declines on Lake Erie, it extends the season during which lake-effect snow may occur. Over the long-term, wintertime precipitation will shift towards lake-effect rainfall, but the region could experience an increase in severe snowstorm events over the next few decades.[146]

The three most vulnerable population groups to severe winter weather are people experiencing homelessness, outdoor workers, and people living in low-income and disinvested communities. The three most vulnerable community systems are ecosystems/environmental health, public health and safety, and energy systems.

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[144] Burnett, Adam W., et al. "Increasing Great Lake–effect snowfall during the twentieth century: A regional response to global warming?." *Journal of Climate* 16.21 (2003): 3535-3542.
Notaro, Michael, Val Bennington, and Steve Vavrus. "Dynamically downscaled projections of lake-effect snow in the Great Lakes basin." *Journal of Climate* 28.4 (2015): 1661-1684.
[145] Data from NEMAC, "The Climate Explorer."
[146] Wuebbles, et al, *An assessment of the impacts of climate change on the Great Lakes*.

Figure 30: Change in the Number of Heating Degree Days in Cleveland (1950-2100)

Source: NEMAC, "The Climate Explorer."

Chapter 5. Adaptive Capacity

As discussed in Chapter 2, the City of Cleveland asked survey respondents to evaluate 21 factors that challenge the ability of a person, their family, or their community's ability to adapt to the impacts of a changing climate. Participants selected top five adaptive capacity factors from this list. Table 11, on page 61, lists all 21 factors included from the survey, along with the number of respondents who reported the factor challenges adaptive capacity. The top five factors - access to basic services, cost of living, access to healthcare, infrastructure conditions and maintenance, and budgetary capacity – appear in green. The table also indicates whether each factor is of low, medium, or high significance for adaptive capacity.[147]

Survey respondents and engagement session participants provided details on their top factors. For access to basic services, one participant in a community engagement session expressed concern over rising utility prices, especially water bills. He indicated that his water service was disconnected during 2023. Climate change may exacerbate these issues, as it raises costs for utilities to maintain infrastructure and increases demand, particularly for air conditioning. Despite its relative affordability, the cost of living has become an increasing concern for Clevelanders. Though the Median Consumer Price Index, which is an indicator used to track inflation, has decreased since February 2023, it is still over twice as high as in February 2021 (4.58% vs. 2.16%).[148] In particular, seniors in Cuyahoga County are struggling to keep up with increasing costs of essentials.[149] A robust social safety net is essential for supporting vulnerable populations as the cost of the living continues to pose a challenge for those whose incomes are not rising proportionally. Despite the prevalence of healthcare institutions and providers in

[147] Factors that scored at or below the 33rd percentile are classified as low significance, factors that scored between the 34th and 67th percentile are classified as medium significance, and factors that scored above the 67th percentile are classified as high significance.
[148] Median CPI, Federal Reserve Bank of Cleveland. 2024. Federal Reserve Bank of Cleveland https://www.clevelandfed.org/indicators-and-data/median-cpi, accessed March 31, 2024.
[149] Tarter et al., January 2024. "Feeling the Pinch: The Daily Impact of Inflation on Cuyahoga County's Older Adults". Center for Community Solutions. https://hhs.cuyahogacounty.gov/docs/default-source/default-document-library/feelingthepinch.pdf?sfvrsn=adcc7b10_3, accessed March 31, 2024.

Cleveland, access to affordable healthcare remains a significant barrier. In 2022, 7.5% of Cleveland residents (27,275 people) did not have health insurance coverage.[150] Mental healthcare is a particular challenge. In a recent survey, 42% of Cuyahoga County residents reported needing mental health assistance in the last few years, but one in five reported not receiving needed assistance. White residents were also more likely to have received help than Black residents.[151]

The budgetary capacity of the City of Cleveland emerged as another priority factor. As one survey respondent noted, "A key responsibility of local government is ensuring there are necessary resources for the community to thrive. Climate change is a threat to the wellbeing of residents. If the community is threatened, the City is responsible for taking steps to mitigate/remove that threat." Rising costs may strain government budgets at all levels, even as the demand for government support increases. According to a 2022 report, just 10 likely impacts of climate change will cost Ohio's local governments $5.9 billion more per year, an 82% increase over current spending.[152] With the passage of the American Rescue Plan Act (ARPA), the Infrastructure Investment and Jobs Act (IIJA), and the Inflation Reduction Act (IRA), the federal government has made a one-in-a-generation investment in helping local governments enhance their capacity and build resilience. While the City of Cleveland must leverage these funding opportunities to help it advance resilience, it must also identify long-term, sustainable funding sources to continue strengthening the adaptive capacity of its residents. For, as another survey respondent explained, "denial and allocation of insufficient resources will only result in greater pain and expenditures in emergencies."

Lastly, respondents indicated that infrastructure conditions and maintenance will affect their ability to cope with a changing climate. The nature and condition of the built environment directly influences the ability of individuals to handle stressors. If a city's stormwater infrastructure does not have the capacity to absorb more than an inch or two of rainfall, residents will suffer from nuisance flooding. If storm sewers are clogged or poorly maintained, even modest rainfall can cause basements to flood. Infrastructure throughout the US, particularly in legacy cities like Cleveland, is aging rapidly. Climate change threatens to strain further these systems, as the climatological conditions they were designed for are disappearing. Changing seasonal conditions are accelerating the traditional freeze-thaw cycle, which strains water and sewer pipes and contributes to the formation of potholes and sinkholes. Worsening HABs on Lake Erie may increase the cost of water treatment for the Cleveland Division of Water by $34 million per year, and Cleveland Public Power may have to spend another $3.4 million on tree pruning to protect power lines from more intense storms.[153] Investing in climate-resilient infrastructure is

[150] 2022 American Community Survey, 5-Year Estimate. "Selected Characteristics of Health Insurance Coverage in the United States". https://data.census.gov/table/ACSST5Y2022.S2701?q=S2701, accessed March 31, 2024.
[151] Center for Community Solutions. March, 2024. "Residents with low income aren't getting the mental health care they need". https://www.communitysolutions.com/residents-with-low-income-arent-getting-the-mental-health-care-they-need/?mc_cid=177b8175a0&mc_eid=f469a7ff2e, accessed March 31, 2024.
[152] Power a Clean Future Ohio (PCFO), The Ohio Environmental Council (OEC), and Scioto Analysis, 2022, *The Bill is Coming Due: Calculating the Financial Cost of Climate Change on Ohio's Local Governments*, Columbus: PCFO & OEC, https://static1.squarespace.com/static/602c33437336ed7a5ac5b3e6/t/62d5af4852f5bb7fd5abc700/1658239260260/OH-MunicipalCostsOfClimateChange.pdf, accessed March 31, 2024.
[153] PCFO, OEC, and Scioto Analysis, *The Bill is Coming Due.*

not just essential for cities; it is also financially sound policy. As one survey respondent said, “maintaining and creating stronger social infrastructure and physical infrastructure (that goes well beyond roadways and is more attentive to non-automobile infrastructure) will be vital in achieving this goal” of preparing Cleveland for a climate-changed future.

Each factor addresses one thing that may affect how Cleveland’s residents adjust to and cope with a changing climate. By identifying the most important factors, the City of Cleveland can better understand where to target interventions that will enhance the resilience of its residents to key climate hazards. For example, access to basic services is the top ranked factor. During an extreme heat event, it is critical for residents to have access to reliable sources of clean water and electricity for cooling. While 43 states, including Ohio, prohibit utility shutoffs during the winter months, just 19 states provide the same protections during heat waves.[154] The City of Cleveland could advocate for similar summertime protections in Ohio. Similarly, the City could adopt stronger labor protections for its employees or for all outdoor workers to protect them from priority climate hazards. These protections could include a municipal action plan for days with poor air quality, similar to Salt Lake City, or an ordinance mandating breaks for outdoor workers on high heat days, like San Antonio.[155]

[154] U.S. Department of Health and Human Services (HHS), “Low-Income Home Energy Assistance Program (LIHEAP) Clearinghouse: Seasonal Termination Protection Regulations,” https://liheapch.acf.hhs.gov/Disconnect/SeasonalDisconnect.htm, accessed March 31, 2024.
[155] Salt Lake City, “Salt Lake City Corporation’s Workforce Air Quality Action Plan,” https://www.slc.gov/sustainability/air-quality/air-quality-action-plan-2/#:~:text=In%202021%2C%20Salt%20Lake%20City,unhealthy%20(Mandatory%20Action%20Days)., accessed March 31, 2024.
Katz, Dan and Joey Palacios. "San Antonio adopts ordinance mandating heat and water breaks for city contractors," Texas Public Radio, September 1, 2023, https://www.tpr.org/government-politics/2023-09-01/san-antonio-adopts-ordinance-mandating-heat-and-water-breaks-for-city-contractors, accessed March 31, 2024.

Table 11: Adaptive Capacity Factors in the City of Cleveland

Factor	Effect on Adaptive Capacity	Number of Respondents Saying Factor Challenges Adaptive Capacity	Significance of Factor to Adaptive Capacity
Access to Basic Services	Having the things you need like water, electricity, and transportation.	183	High
Access to Education	Going to school and learning (K-12 schooling, ESL courses, college classes, education for your job, etc.)	53	Medium
Access to Healthcare	Being able to get medical care when you need it.	108	High
Budgetary Capacity	The city government has enough money to do its job.	88	High
Community Engagement	Involving people in making decisions about the city.	62	Medium
Cost of Living	How much it costs to live in the city, including housing and food.	130	High
Economic Diversity	The city has a variety of businesses and industries	19	Low
Economic Health	How well the city's economy is doing	63	Medium
Government Capacity	The city government has the skills and resources to do its job.	53	Medium
Having a Place to Live	Having a place to live.	61	Medium
Inequality	Some people have more money and resources than others.	68	High
Infrastructure Capacity	How much of the populations needs the city's infrastructure, such as roads and bridges, can handle.	47	Low
Infrastructure Conditions and Maintenance	How well the city's infrastructure, such as roads and bridges, is kept in working condition.	89	High
Land-Use Planning	Planning how to use the land in the city.	57	Medium
Migration	Migration: More people moving in, around, or out of the City of Cleveland.	28	Low
Political Engagement and Transparency	The city government is open to hearing from people and is clear about its actions.	36	Low
Poverty	Not having enough money to meet your basic needs.	49	Medium
Public Health	Being healthy, not getting sick, and being able to get medical care if you need it.	80	High
Rapid Urbanization/ Resource Availability	How quickly the city is growing and how many resources are available to meet the population’s needs.	32	Low
Safety and Security	Feeling safe in the city.	46	Low
Unemployment	Not having a job	15	Low

Chapter 6. Conclusion

This report represents an important step towards strengthening Cleveland's resilience to climate change. As this CRVA has demonstrated, the climate in the City of Cleveland has become warmer, wetter, and more unpredictable in recent decades. Not only will that trend continue over the coming decades; it will accelerate. However, given Cleveland's temperate climate, abundant freshwater resources, and relative insulation from some of the most severe impacts of climate change (e.g. sea level rise, wildfires), there remains a perception that the city will be a climate refuge. While this may be true, to some extent, and research does suggest that people living in vulnerable regions may turn to the Great Lakes to escape the impacts of climate hazards, the City of Cleveland cannot get complacent.[156] Climate change will spare no region, and the evidence gathered in this report makes it clear that the residents of many of Cleveland's neighborhoods are nearly as vulnerable to climate hazards as are people living in areas like the Gulf Coast.

This CRVA is an important first step, but it is just that. If the City truly wishes to leverage its advantageous location, it must act now to prepare for the priority climate hazards identified in this report and to help enhance the resilience of its vulnerable population groups and community systems. The City is building off this report to develop its Climate Action Plan update. In particular, the City and its partners are using this assessment's findings – key climate hazards, vulnerable population groups, vulnerable community systems, and adaptive capacity factors – to develop policies and programs to enhance resiliency within Cleveland. This document will also be an important guide as the City and its partners implement these actions in the coming years.

Addressing the causes and preparing for the impacts of climate change is a process, not an outcome. The process is perpetual and evolutionary, and the City must continue to revisit and revise this assessment in the coming years as the climate crisis shifts and evolves. Cleveland is committed to acting on climate change in a proactive manner, and the City will revisit and improve this report each time that it updates it Climate Action Plan.

[156] Hauer, Mathew E. "Migration induced by sea-level rise could reshape the US population landscape." *Nature Climate Change* 7.5 (2017): 321-325.

Appendix A

Cleveland Community Climate Vulnerability and Risk Assessment Survey Introduction

The City of Cleveland is committed to sustainability and equity. We want to ensure that everyone in our community has a safe and healthy place to live, regardless of income, race, or ability. We are working to make our city more resilient to climate change that is equitable and inclusive of all communities. We want to hear about how climate change affects you and your community and how we can work together to build a more sustainable and equitable future for Cleveland.

Climate change describes a change in the average conditions — such as temperature and rainfall — in a region over a long period of time. Human activity is causing worldwide temperatures to rise higher and faster than any time that we know of in the past. In Cleveland, we are seeing more extreme weather events, like severe storms, more rain flooding, extreme heat, and warmer seasons. These events can cause damage to homes and businesses and make it harder for people to stay healthy.

The City of Cleveland is updating its Climate Action Plan to help us prepare for and adapt to the impacts of climate change. The plan will include strategies to reduce greenhouse gas emissions, the main cause of climate change. It will also include strategies to help our communities become more resilient to, or able to bounce back from, the impacts of climate change.

How to take the survey

Please respond to each question in the survey. Please read each question before responding to ensure that your answers are complete and accurate to the best of your ability. Once you finish the survey, click submit so that your answers are recorded. **This survey should take approximately ten to fifteen (10-15) minutes to complete. Please return and complete this survey by November 16th at the latest.**

We are raffling off five $20 gift cards to Dave's Supermarket for people who complete the survey. Limit one prize per person.

Participant Information

Please circle one option for each question. Please select one option for each question. Your answers will remain anonymous. Often people who live in disinvested communities are not included in city decision-making processes. This information about you will help us better understand who is most impacted by climate hazards and how the City of Cleveland can better prioritize resources to invest in your community.

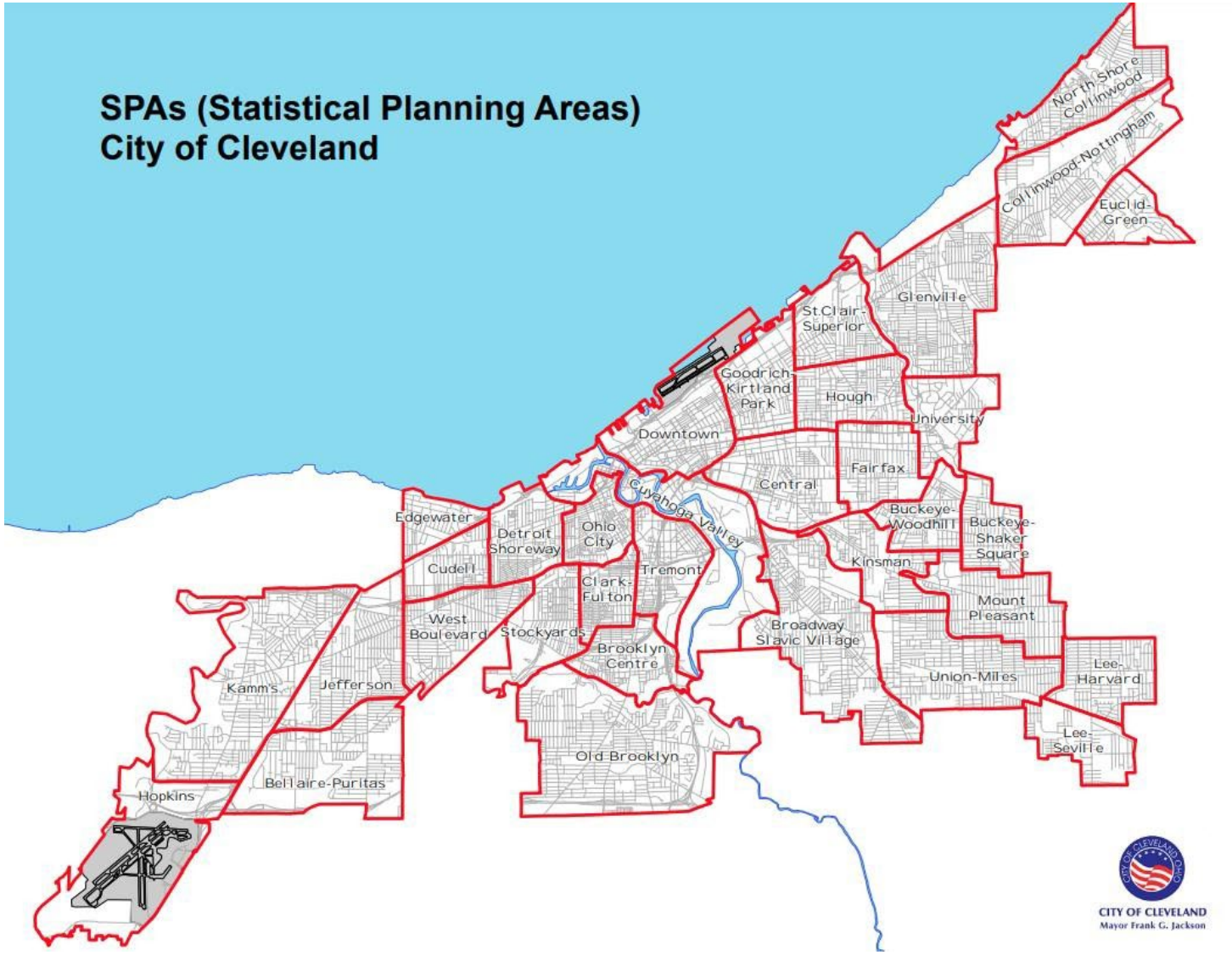
- **Age**: Under 18, 18-24, 25-34, 35-49, 50-65, Over 65, Prefer not to say
- **Sex/gender**: Female, Male, Non-binary, Prefer not to say, Other (please specify)
- **Race/ethnicity:** White, Black or African American, American Indian or Alaska Native, Asian, Native Hawaiian or Other Pacific Islander, Prefer not to say, Other (please specify)
- **Household income:** $0-24,999, $25,000-49,999, $50,000-74,999, $75,000-99,999, Over $100,000, Prefer not to say
- **Level of Education**: Less than high school, High school diploma or GED, Some college, Associate's degree, Bachelor's degree, Graduate or professional degree, Prefer not to say
- **Living Situation:** Owns home, Rents home, Lives with friends or family, Lives in student housing, No permanent housing, Prefer not to say, Other (please specify),

- **Home neighborhood:**

Bellaire-Puritas	Cuyahoga Valley	Hough	Old Brooklyn
Broadway-Slavic Village	Detroit Shoreway	Jefferson	Saint Clair-Superior
Brooklyn Centre	Downtown	Kamms Corners	Stockyards
Buckeye-Shaker Square	Edgewater	Kinsman	Tremont
Buckeye-Woodhill	Euclid-Green	Lee-Harvard	Union-Miles
Central	Fairfax	Lee-Seville	University
Clark-Fulton	Glenville	Mount Pleasant	West Boulevard
Collinwood-Nottingham	Goodrich-Kirtland Park	North Shore Collinwood	Other (outside of Cleveland)
Cudell	Hopkins	Ohio City	

- **Work neighborhood:**

Bellaire-Puritas	Cuyahoga Valley	Hough	Old Brooklyn
Broadway-Slavic Village	Detroit Shoreway	Jefferson	Saint Clair-Superior
Brooklyn Centre	Downtown	Kamms Corners	Stockyards
Buckeye-Shaker Square	Edgewater	Kinsman	Tremont
Buckeye-Woodhill	Euclid-Green	Lee-Harvard	Union-Miles
Central	Fairfax	Lee-Seville	University
Clark-Fulton	Glenville	Mount Pleasant	West Boulevard
Collinwood-Nottingham	Goodrich-Kirtland Park	North Shore Collinwood	Other (outside of Cleveland)
Cudell	Hopkins	Ohio City	



- **Years lived in the City of Cleveland**: _____

Personal Climate Impacts and Concerns

Please check the following boxes to express your stance on the following statements.

Concerns	Completely disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Completely agree
I am concerned that climate change will affect me and my family.					
I am concerned that climate change will affect my community.					

Over the past 3 years, have you personally experienced any of the following climate hazards? Select all that apply.

- ❑ Changes to Lake Erie (harmful algal blooms, less ice cover, changing water levels)
- ❑ Changing seasonal conditions (e.g. warmer, shorter winters)
- ❑ Extreme heat (one or more days with temperatures above 95^{o}F)
- ❑ Groundwater flooding (flash flooding due to heavy rainfall, basement flooding/sewer backups, etc.)
- ❑ Heatwave (three or more days with temperatures above 90^{o}F)
- ❑ Insect infestation (e.g. damage to crops and plants from insect populations)
- ❑ Invasive plant species (e.g. non-native plants and animals that cause harm)
- ❑ Poor Air Quality (e.g. smog)
- ❑ River flooding (flash flooding from nearby rivers and streams due to heavy rainfall, etc.)
- ❑ Severe summer thunderstorms that caused damage to your community or your personal property (e.g., damage caused by hail, lightning, high winds, or tornadoes)
- ❑ Severe winter storms that caused damage to your community or your personal property (e.g., damage caused by ice, high winds, or heavy snow)
- ❑ Other (please specify) _____

Check the box for each hazard that has prevented you from doing the things you need to do each day in the last three years, such as going to school, work, or the doctor, caring for family, and keeping your home powered.

Climate Hazard	Yes	No	Unsure
Changes to Lake Erie			
Changing Seasonal Conditions			
Drought			
Extreme Heat			
Heavy Precipitation & Flooding			
Insect Infestation			
Invasive Plant Species			
Poor Air Quality			
Severe Summer Storms			
Severe Winter Weather			

If you answered yes to any of the above questions, please describe the activities you could not do.

Top Climate Hazards

This section asks you to think about how climate change might affect you or your community in the next 20-30 years. Please mark whether you think each hazard has a low, moderate, or high level of likelihood of affecting you. If you do not know, please select that option.

Climate Hazard	Low Likelihood	Moderate Likelihood	High Likelihood	Do Not Know
Changes to Lake Erie				
Changing Seasonal Conditions				
Drought				
Extreme Heat				
Heavy Precipitation & Flooding				
Insect Infestation				
Invasive Plant Species				
Poor Air Quality				
Severe Summer Storms				
Severe Winter Weather				

This section asks you to think about how much harm climate change cause for you or your community in the next 20-30 years. Please mark whether you think each hazard has a low, moderate, or high level of impact on you, your family, and your community. If you do not know, please select that option.

Climate Hazard	Low Harm	Moderate Harm	High Harm	Do Not Know
Changes to Lake Erie				
Changing Seasonal Conditions				
Drought				
Extreme Heat				
Heavy Precipitation & Flooding				
Insect Infestation				
Invasive Plant Species				
Poor Air Quality				
Severe Summer Storms				
Severe Winter Weather				

Who are most likely to be affected by climate change?

Climate change can affect everyone, but some people are more at risk than others. These people are called vulnerable populations. Vulnerable populations may need more access to resources and support or may have other challenges that make it harder for them to cope with the effects of climate change.

Please choose which of the following groups of people are most vulnerable to each of the climate hazards listed. Please select up to five (5) groups for each hazard.

Groups of People (Mark 5 for each hazard)	**Hazards**				
	Changes to Lake Erie	Changing Seasonal Conditions	Drought	Extreme Heat	Heavy Precipitation & Flooding
Children					
Communities of Color					
Outdoor Workers					
People experiencing homelessness					
People living in low-income/ disinvested communities					
People with less than a high school education					
People with limited English proficiency					

Groups of People (Mark 5 for each hazard)	**Hazards**				
	Changes to Lake Erie	Changing Seasonal Conditions	Drought	Extreme Heat	Heavy Precipitation & Flooding
People with low income					
People with medical conditions and/or disabilities					
People without a car					
Renters					
Senior citizens					
Other (Fill in)					
Groups of People (Mark 5 for each hazard)	**Hazards**				
	Insect Infestation	Invasive Plant Species	Poor Air Quality	Severe Summer Storms	Severe Winter Weather
Children					
Communities of Color					
Outdoor Workers					
People experiencing homelessness					
People living in low-income/ disinvested communities					

Groups of People (Mark 5 for each hazard)	**Hazards**				
	Insect Infestation	Invasive Plant Species	Poor Air Quality	Severe Summer Storms	Severe Winter Weather
People with low income					
People with medical conditions and/or disabilities					
People without a car					
Renters					
Senior citizens					
Other (Fill in)					

These groups of people may be more vulnerable to climate change for several reasons, such as:

- They may live in areas more prone to climate hazards like flooding or extreme heat.
- They may have less access to resources like air conditioning or transportation, making staying safe during extreme weather events harder.
- They may have other challenges, such as poverty or health problems, that make it harder for them to cope with the effects of climate change.

What systems and assets are most likely to be affected by climate change?

Vulnerability is the likeliness to suffer negative effects from hazards. Vulnerability includes being sensitive to harm and less able to adapt to those harms.

Assets mean people, resources, communities, infrastructure, and the services those things provide. They include the things that people or communities value.

A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot, such as our power system.

This section will ask you a series of questions about vulnerable assets. When these assets and systems become damaged for any reason, quality of life may suffer. Please mark up to three (3) assets/systems that are relevant to you, your family, or your community in the boxes under each hazard. There are two tables of hazards. Not every asset will have a check mark and some assets may have multiple.

Assets/Systems (Choose 3 for each hazard)	**Hazards**				
	Changes to Lake Erie	Changing Seasonal Conditions	Drought	Extreme Heat	Heavy Precipitation & Flooding
Community and Cultural Assets & Systems (e.g. churches, libraries, community centers)					
Ecosystems and Environment Health (e.g. air quality, water quality, tree cover)					
Educational Assets & Systems (Cleveland Metropolitan School District, tutoring services, ESL courses, college classes)					

Assets/Systems (Choose 3 for each hazard)	**Hazards**				
	Changes to Lake Erie	Changing Seasonal Conditions	Drought	Extreme Heat	Heavy Precipitation & Flooding
Energy Assets & Systems (e.g. public power and electricity)					
Food and Agriculture Assets & Systems (e.g. food pantry distribution)					
Housing Assets & Systems (e.g. City of Cleveland public housing)					
Industrial Assets & Systems (e.g. manufacturing plants, power plants)					
Information & Communications Technology Assets & Systems (e.g. internet, telephones)					
Public Health & Safety (e.g. medical care facilities, emergency response services)					
Transportation Assets & Systems (e.g. RTA transit and bus lines, roadways, sidewalks, bike lanes)					
Water and Wastewater Management Assets & Systems (e.g. wastewater treatment plant, drinking water)					

Assets/Systems (Choose 3 for each hazard)	**Hazards**				
	Insect Infestation	Invasive Plant Species	Poor Air Quality	Severe Summer Storms	Severe Winter Weather
Community and Cultural Assets & Systems (e.g. churches, libraries, community centers)					
Ecosystems and Environment Health (e.g. air quality, water quality, tree cover)					
Educational Assets & Systems (Cleveland Metropolitan School District, tutoring services, ESL courses, college classes)					
Energy Assets & Systems (e.g. public power and electricity)					
Food and Agriculture Assets & Systems (e.g. food pantry distribution)					
Housing Assets & Systems (e.g. City of Cleveland public housing)					
Industrial Assets & Systems (e.g. manufacturing plants, power plants)					
Information & Communications Technology Assets & Systems (e.g. internet, telephones)					

Assets/Systems (Choose 3 for each hazard)	**Hazards**				
	Insect Infestation	Invasive Plant Species	Poor Air Quality	Severe Summer Storms	Severe Winter Weather
Public Health & Safety (e.g. medical care facilities, emergency response services)					
Transportation Assets & Systems (e.g. RTA transit and bus lines, roadways, sidewalks, bike lanes)					
Water and Wastewater Management Assets & Systems (e.g. wastewater treatment plant, drinking water)					

How do people adapt to Climate Change?

This section asks you to think about how well the City of Cleveland can change to adapt to, or cope with, climate change. Please **check up to five (5)** of the following factors that will impact your, your family's, or your community's ability to adapt to the impacts of a changing climate.

- **Access to basic services**: Having things you need like water, electricity, and transportation.
- **Access to education**: Going to school and learning (K-12 schooling, ESL courses, college classes, education for your job, etc.)
- **Access to healthcare:** Being able to get medical care when you need it.
- **Access to quality/relevant data**: Having access to information that helps make decisions.
- **Budgetary capacity**: The city government has enough money to do its job.
- **Community engagement**: Involving people in making decisions about the city.
- **Cost of living**: How much it costs to live in the city, including housing and food.
- **Economic diversity:** The city has a variety of businesses and industries.
- **Economic health**: How well the city's economy is doing.
- **Government capacity**: The city government has the skills and resources to do its job.
- **Housing:** Having a place to live.
- **Inequality**: Some people have more money and resources than others.
- **Infrastructure capacity**: How much of the population's needs the city's infrastructure, such as roads and bridges, can handle.
- **Infrastructure conditions and maintenance**: How well the city's infrastructure, such as roads and bridges, is kept in working condition.
- **Land use planning:** Planning how to use the land in the city.
- **Migration:** More people moving in, around, or out of the City of Cleveland
- **Political engagement and transparency**: The city government is open to hearing from people and is clear about its actions.
- **Political stability:** The city government is stable and not likely to change.

How do people adapt to Climate Change (Continued)?

- **Poverty:** Not having enough money to meet your basic needs.
- **Public health:** Being healthy, not getting sick, and being able to get medical care if you need it.
- **Rapid urbanization/Resource availability:** How quickly the city is growing and how many resources are available to meet the population's needs.
- **Safety and security**: Feeling safe in the city.
- **Unemployment:** Not having a job.
- **Other:** _____

Do you agree or disagree with the following statement? The City of Cleveland should devote significant attention and resources to making the community more able to cope with climate change. Circle your answer.

- Completely disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Completely agree

Please explain why you feel this way:_____

_____

OPTIONAL: Would you be interested in being involved (e.g. attend focus groups and public engagement sessions, volunteer, participate in a working group, etc.) in Cleveland's Climate Action Planning process throughout 2023-2024? If so, please provide your name, email address, and/or phone number where we can contact you with additional opportunities to participate.

Name: Phone number:

Email address:

Thank you for completing the survey! Please return this survey to 75 Erieview Plaza 1st floor, Suite #115 Mayor's Office of Sustainability, Cleveland, OH 44114, or call (216) 664-2455 for assistance.