
EVERETT
SOMERVILLE
CHARLESTOWN
CAMBRIDGE
WATERTOWN
East Boston Memorial Park
Maverick
DOWNTOWN
ALLSTON/ BRIGHTON
Packards Corner
CHINATOWN
Tufts Med
Brighton
FENWAY/ KENMORE
SOUTH END
NEWTON
Mass Ave
SOUTH BOSTON
Brigham Circle
Ruggles
BROOKLINE
Roxbury Crossing
Nubian Sq
Newmarket
Joe Moakley Park
Jackson Sq
ROXBURY
JFK/UMass
Jamaica Pond
Uphams Corner
Savin Hill
JAMAICA PLAIN
Four Corners/ Geneva
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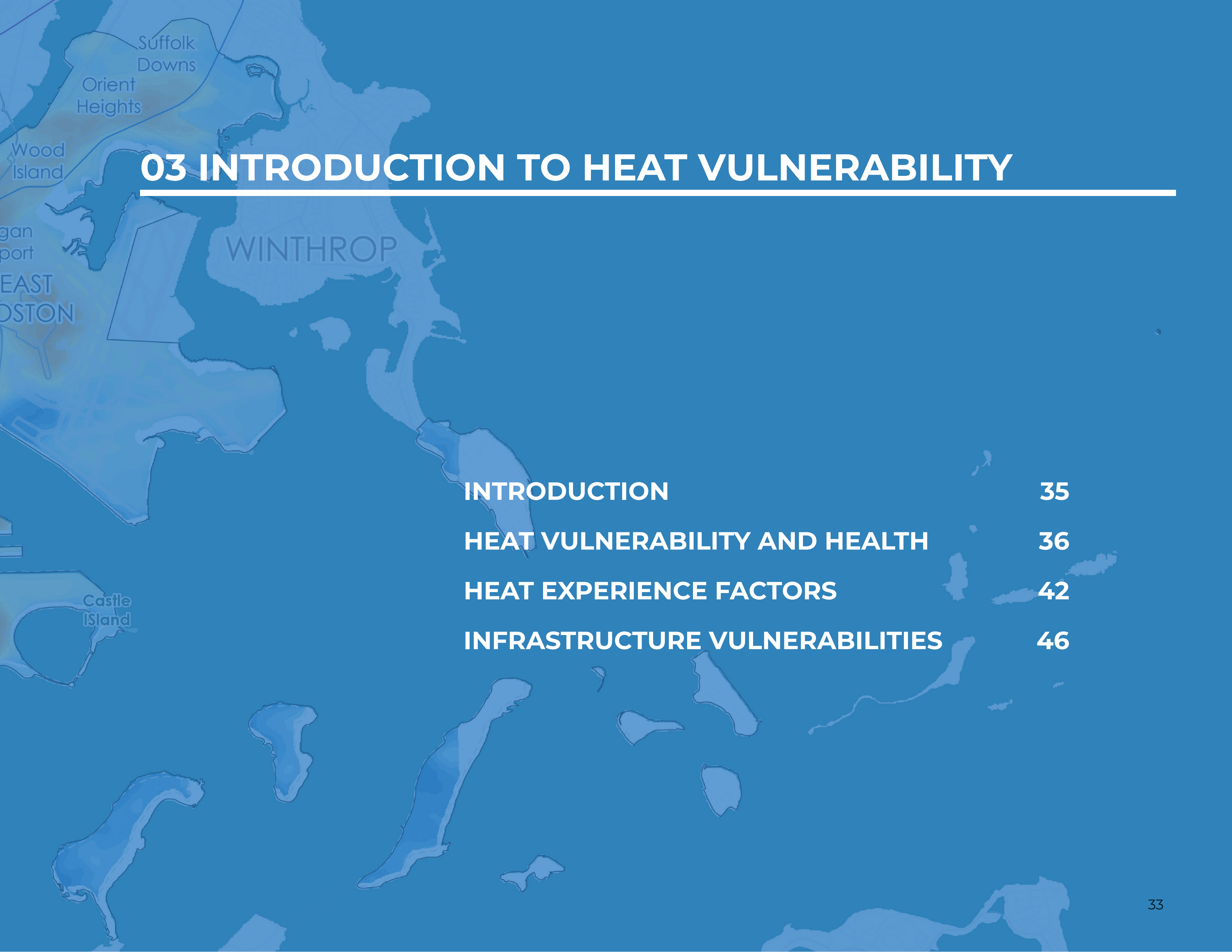

03 INTRODUCTION TO HEAT VULNERABILITY


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INTRODUCTION

This chapter introduces concepts related to heat vulnerability, and discusses the relationship between high heat and public health. Additionally, this chapter dives into the multiple factors that affect residents' heat experiences. Lastly, this chapter briefly touches on how high heat also affects the infrastructure in the city. To help with understanding heat vulnerability, risk, and resilience, below is a list of common heat resilience terms that will show up throughout in the Heat Plan.

COMMON HEAT RESILIENCE TERMS

Air Temperature: Air temperature can be influenced by humidity, wind flow, building form, surfaces (ground, walls, roofs), and the surrounding atmosphere.

Land Surface Temperature: The temperature of surfaces is influenced by a variety of factors including land cover, reflectivity, location, time of day and year, cloud cover, wind flow, and shadows.

Perceived Temperature: What the surrounding temperature feels like to the human body. It takes into account humidity, temperature, solar, and wind exposure.

Universal Thermal Climate Index: Measurement used for perceived thermal comfort. Boston's average summer perceived temperature is 73°F. Summer daytimes are generally warm to hot with moderate to high heat stress.

Relative Humidity: The percentage of water vapor in the atmosphere that can be retained in the atmosphere without condensation.

Extreme Heat: A prolonged period of very hot weather, which may include high humidity.[1]

Urban Heat Island: Urban areas that experience higher temperatures than outlying areas (buildings and roads absorb the sun's heat more than forests or water bodies).

Heat Wave: Three or more consecutive days above 90°F.

Heat Alert: In Boston, this is issued when there is a heat wave.

Heat Advisory: In Boston, this is declared when there is a heat wave, which is a period of three or more consecutive days above 90°F heat index.[2]

Heat Emergency: In Boston, this is declared when there is a period of two or more consecutive days above 95°F heat index, and the overnight temperature does not fall below 75°F.

Vulnerability: The disproportionate susceptibility of some social groups to the impacts of hazards, including death, injury, or disruption of livelihood.

Heat Vulnerability: How likely someone is to experience heat-related health problems.

Heat Exposure: The amount of heat people, the environment, systems, or other elements experience or are subject to. Exposure considers both heat intensity as well as duration.

Heat Sensitivity: The degree to which people, the environment, systems or other elements are affected by exposure to heat.

Adaptive Capacity: The ability to adjust to climate change, to moderate potential damages, to take advantage of opportunities, or to cope with consequences.

Heat Stress: When a person is exposed to extreme heat or in a hot environment, they are at risk of heat stress. Continued heat stress can increase the risk of heat related illness and injuries.

Heat Related Illness: Illness caused by high temperatures and humidity, which can include symptoms like muscle spasms, headaches, and dizziness. The most common heat-related illnesses include heat rash, heat cramps, heat exhaustion, and heat stroke.

Heat Exhaustion: Blood flow to vital organs decreases.

Heat Stroke: Body systems begin to stop functioning due to heat.[3]

HEAT VULNERABILITY AND HEALTH

The risks associated with extreme heat disproportionately affect some people and communities more than others. There are three main factors that affect heat vulnerability: exposure, sensitivity, and adaptive capacity.

HEAT EXPOSURE

Some people experience greater exposure to extreme heat than others. People with elevated heat exposure include those with jobs, living situations, or hobbies in outdoor or indoor environments without adequate shade to block direct sunlight or ventilation to circulate cool air flow. Examples of people with elevated heat exposure include people experiencing homelessness, residents in temperature hotspots, outdoor workers, and athletes.

Greater heat exposure can also be a result of the surrounding built environment. While all of Boston experiences extreme heat, there are localized temperature hot spots across the city where the risks of extreme heat are greater. For example, areas adjacent to dark, paved surfaces without canopy cover experience higher temperatures as a result of direct sunlight that is absorbed by the surface. Frequent and prolonged exposure to heat and extreme heat can cause dehydration and heat-related illness, including heat cramps, heat exhaustion, and heat stroke.[4]

EXAMPLES OF PEOPLE WITH ELEVATED HEAT EXPOSURE

- People experiencing homelessness
- Residents of hot neighborhoods
- Outdoor workers
- Athletes

From a worker health perspective, we definitely need to provide more support for outdoor workers and policies requiring more shade and water breaks for heat waves.
-open house participant

HEAT SENSITIVITY

In addition to heat exposure, heat vulnerability is also affected by how sensitive one may be to extreme heat. People with elevated heat sensitivity include those with chronic health conditions (especially respiratory conditions), children, and older adults. People with chronic health conditions can be more vulnerable to heat as they may be less likely to sense changes in temperature or may be taking medications that can make the effects of heat worse. Children and youth often rely on others to keep them cool and hydrated when it is hot outside, and may not understand the signs of heat-related illness before they become more severe. Older adults do not adjust as well as younger people to sudden temperature changes and are more likely to have chronic medical conditions that change their body response to heat.[5]

EXAMPLES OF PEOPLE WITH GREATER HEAT SENSITIVITY:

- People with chronic health conditions (e.g., asthma, diabetes)
- Children and youth
- Older adults

ADAPTIVE CAPACITY

A person's ability to adapt to extreme heat by taking measures to cool themselves also affects their heat vulnerability. The ability to access cooling resources is a critical factor of adaptive capacity. Low adaptive capacity can result from barriers to opportunities and resources that help cope with heat stress. People with lower adaptive capacity may be unable to make their immediate surroundings cooler or more comfortable, to relocate to a cooler place, or to receive help from others nearby.

EXAMPLES OF PEOPLE WITH LOWER ADAPTIVE CAPACITY:

- Individuals who live alone or do not have close social contacts to reach out to for support
- Homebound individuals or people with limited mobility
- Individuals without air conditioning or who need to limit its use due to utilities affordability
- Individuals lacking access to transportation
- Individuals facing language barriers

BOSTON'S RISK FROM EXTREME HEAT IMPACTS THE ENTIRE CITY POPULATION

As a coastal city, Boston is preparing for the impacts of multiple climate hazards including sea-level rise, coastal storms, extreme precipitation, and extreme heat.

Significant planning has already been completed for Boston's coastal neighborhoods. This plan brings a similar focus to heat resilience. Both flooding and extreme temperature hazards pose increasing challenges for Boston's residents, businesses, and infrastructure, but vary in important ways.

Extreme heat affects all of Boston today.

While some neighborhoods and residents experience greater extreme heat risks, all of Boston is hotter than surrounding suburban and rural areas and is at risk during heat waves.

Extreme heat impacts cause significant health risks.

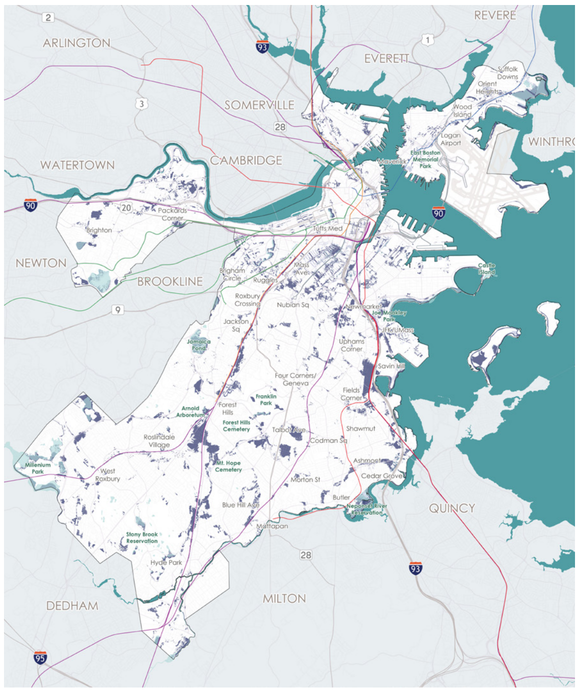
In Boston, the health impacts associated with extreme heat risk are a critical concern. Hot weather can cause heat exhaustion and heat stroke. It can also exacerbate symptoms of underlying health conditions including asthma, diabetes, and other respiratory and cardiovascular conditions. Extreme heat days can increase air pollutants like smog that can further aggravate respiratory symptoms and asthma.

Even though heat-related illnesses are largely preventable,6 warning symptoms can go undetected or untreated. Many Bostonians lack access to the basic resources—air conditioning, water, rest, and shade—needed to keep their bodies at a healthy temperature during their daily home, work, school, and transportation routines. Two national studies on deaths attributed to heat impacts have estimated about 50 to 100 heat-attributable deaths for an average Boston summer.7 As Boston gets hotter, taking additional actions to equitably protect the health and safety of residents through investments in heat resilience is critical.

Extreme heat is already a daily stressor for many Bostonians during hot weather.

Heat is already a chronic stressor for daily life for many Bostonians across the city. Imagine a Bostonian without home air conditioning who commutes to work on foot or by bus, or perhaps works outside. If bus stops lack shade, the wait for a bus could be even less comfortable. This person will experience cumulative heat exposure while outdoors and while commuting—and will have little relief at home and overnight. The *Heat Plan* considers a continuum of experiences to plan for heat resilience needs. Recognizing how extreme heat can affect various aspects of daily routines, the *Heat Plan* identifies heat resilience interventions and investments focused on a broad range of daily activities to protect the health and safety of residents and workers.

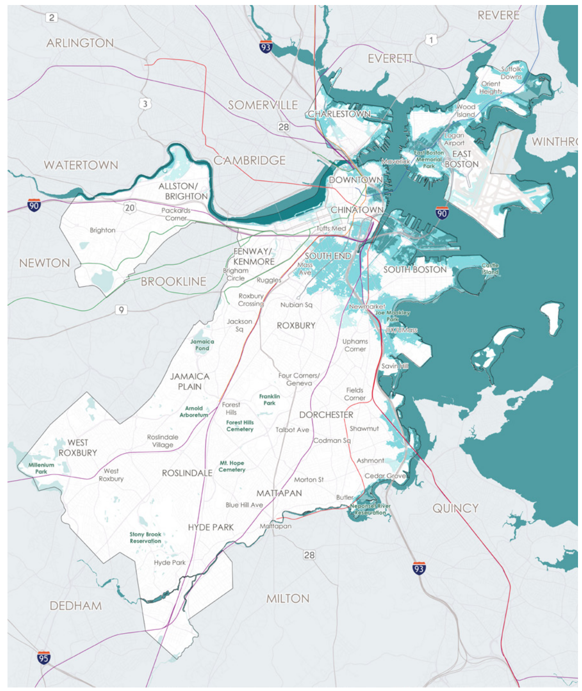
Green infrastructure to reduce stormwater flooding could also reduce temperatures.



STORMWATER FLOODING
36" SLR - 2070S OR LATER

- *Near-term (2030s-2050s)*
- *Medium-term (2050s-2070s)*
- *Long-term (2070s onwards)*

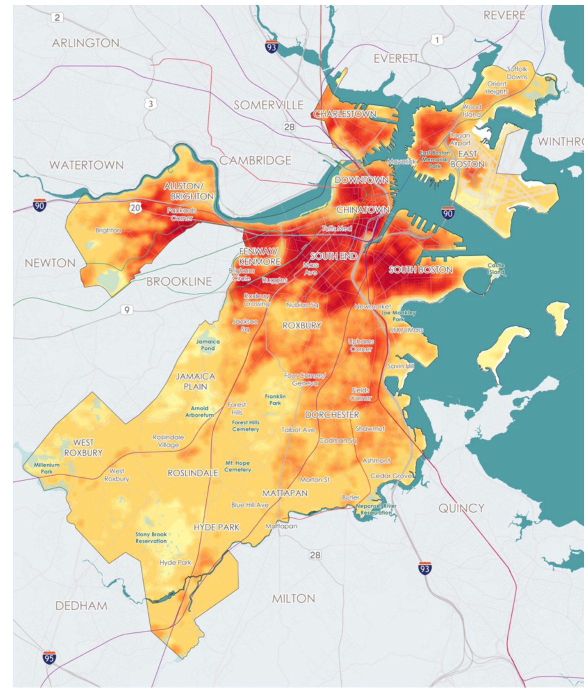
Coastal flooding risk will increase over the coming decades. Synergies with heat resilience are possible with waterfront strategies that reduce flood risk.



FLOOD PROGRESSION MAP
36" SLR - 2070S OR LATER

- *Average Monthly High Tide*
- *10% Annual Chance Storm*
- *1% Annual Chance Storm*

Extreme heat already affects all of Boston. Some areas experience longer, hotter high-heat conditions.



HEAT EVENT HOURS
MODELING BASED ON JULY 2019 DATA

Less than 25 hrs — *More than 37 hrs*

INCREASES IN HEAT RISK AND PUBLIC HEALTH IMPACTS

If greenhouse gas emissions continue at the current rate, it is likely that Boston will have up to about 60 days over 90°F each year by the 2070s—and up to about 80 days over 90°F each year by the 2080s.

Future temperatures in Boston will depend on how much we are able to cut our greenhouse gas emissions. If emissions trends continue at the current rate (RCP 8.5), climate projections estimate that the number of very hot days (over 90°F) will most likely (17th to 83rd percentile) increase from 10 days in the 2000s[8] to 33 to 62 days by 2070. Under a reduced emissions scenario (RCP 4.5), the number of very hot days (over 90°F) is projected to most likely be 22 to 43 days by 2070.[9] Even if emissions are reduced, Bostonians will face increasing heat risk.

Today, the impact of extreme heat on health is evident when looking at daily Boston EMS clinical incidents.[i] Daily heat-related[ii] EMS incidents data from 2012 to 2021 show there was an overall rise in incidents during the summer months (June to August) compared to the rest of the year.[10] In 2021, June saw the second highest number of incidents (92 incidents), indicating that the two heat waves in June, one of which was a heat emergency, played a role in the spike of heat-related illnesses. During a five-day heat wave in June 2021 where temperatures exceeded 90°F, the total of heat-related EMS incidents was 48, with a peak of 14 incidents on a single day when temperatures hit 95°F. In the five days after the heat wave, the average maximum temperature was 82°F, and only two incidents occurred. This data might be missing incidents not directly classified as heat or heat exhaustion, meaning that incidents indirectly related to heat might not be accounted for in these numbers.

Boston EMS responds to an average of 347 clinical incidents per day. During heat emergencies it is common to see a 20% or more increase in call volume, at times exceeding 100 additional clinical incidents in a single day.[11] An overall rise in incidents during heat waves and emergencies is clear, but the full extent might not be apparent. Police and fire dispatch calls also increased during extreme heat, suggesting there are indirect effects of heat on people's behavior and health.[12]

"Extreme heat can cause negative health impacts, including direct loss of life, increases in respiratory and cardiovascular diseases, and challenges to mental health." -2016 Climate Ready Boston

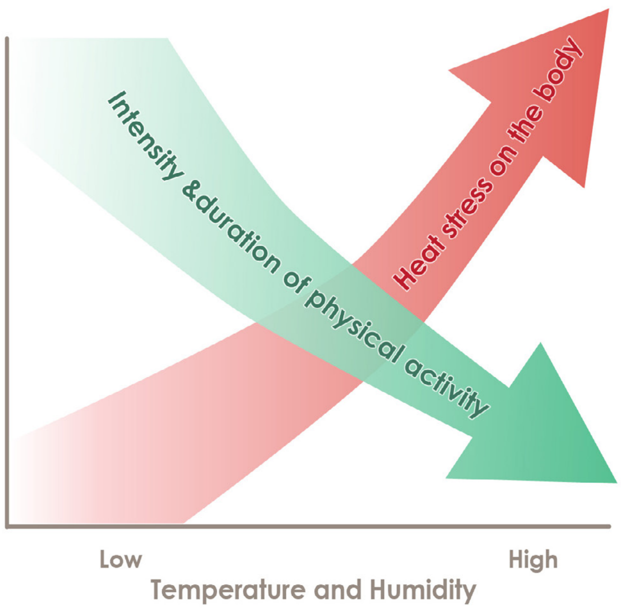
It is not just about days over 90°F. If greenhouse gas emissions continue at the current rate, it's likely that Boston will have up to 130 days over 80°F—and up to 14 days over 100°F— by the 2070s.

i A Boston EMS clinical incident is typically generated by someone calling 911 for a medical emergency resulting in the dispatch of an ambulance.

ii These counts include patient encounters with either a type code of "Heat" or a clinical impression related to heat, such as "Heat exhaustion." However, the data may be missing some counts that don't have these classifications (indirect heat-related incidents).

HEAT, PHYSICAL ACTIVITY, AND HEAT STRESS

When temperature and relative humidity increase, the likelihood of heat disorders with prolonged exposure or strenuous activity increases, and can cause major health and safety concerns.[17] The increased heat stress on the body exacerbates preexisting health conditions. To prevent this, people should limit or decrease their intensity of physical activity and stay hydrated.



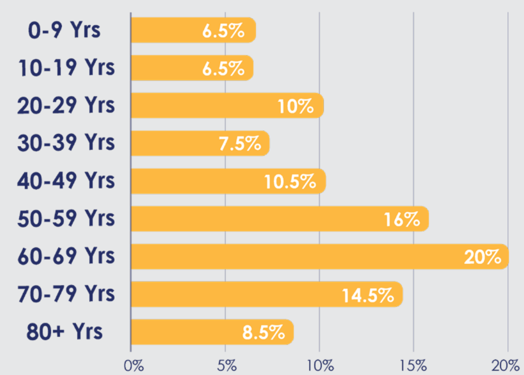
Prolonged exposure and strenuous activity increases the danger of heat-related illness and exacerbates pre-existing health conditions

To prevent heat-related illness, people should limit or decrease intensity of physical activity and stay hydrated.

ASTHMA AND HEAT

In Massachusetts, 10.2% of adults and 12.9% of children, about one out of eleven people, live with asthma.[13] Research shows that extreme heat can worsen asthma, and even increase hospitalization rates and total costs.[14 15] A 2010 study led by Boston EMS, BPHC, and the Centers for Disease Control and Prevention (CDC) found that hospitalization rates for asthma was highest in Black and Hispanic populations in children under five, and those living in large multi-family affordable communities were exposed to more risk factors.[16] More recently, data from Boston EMS (2018-2020), show that asthma EMS incidents are more prevalent for adults aged 60 to 69 years old. The disproportionate burden of both asthma and heat can create a compounding effect on at-risk populations. As a result, heat is more dangerous, and heat resilience strategies need to prioritize providing cooling to these communities.

PERCENT OF TOTAL ASTHMA INCIDENTS BY AGE GROUP FROM 2018-2020



Data Source: Boston EMS, 2018 - 2020 Asthma Incidents

HEAT EXPERIENCE FACTORS

Heat experiences are a result of multiple factors. Air temperature, humidity, and wind influence individual experiences with extreme heat risk. There are also compounding factors in addition to weather conditions, which affect heat experiences.

PERSONAL HEALTH AND COOLING ACCESS

Chronic health conditions and age can increase vulnerability to heat risk.

Similarly, physical and financial access to cooling can also affect heat exposure. This includes affordability of home air conditioning or the ability to relocate to other air conditioned spaces.

PHYSICAL ENVIRONMENT (BUILT AND NATURAL)

Trees and parks help cool off neighborhoods, while denser neighborhoods and large amounts of pavement make them heat up more and stay hot longer.

A neighborhood's characteristics and surroundings influence its air temperature. Factors that make a neighborhood hotter include the following:

- Denser buildings, especially if buildings are typically brick or have dark roofs
- Large amounts of pavement, especially if it is unshaded
- Fewer trees or green spaces
- A location that is not within a few blocks of the waterfront or a large park

AIR FLOW

The dynamic nature of air shapes how individuals and neighborhoods experience heat.

How well air can move influences how much hot air builds up in a given location and how much cool air can displace it to provide relief. Green spaces and coastal breezes are sources of cooling air flow that can bring cooler air to surrounding blocks. Cooling effects can spread more effectively with space between buildings and infrastructure for air to flow. Franklin Park effectively provides a large-scale natural cooling source that helps the adjacent area stay 5 to 7°F cooler than areas a few more blocks inland.[i] In contrast, without air flow, there is little room for the hot air to escape. These areas tend to remain hotter overnight.

HISTORY AND STRUCTURAL INEQUITY

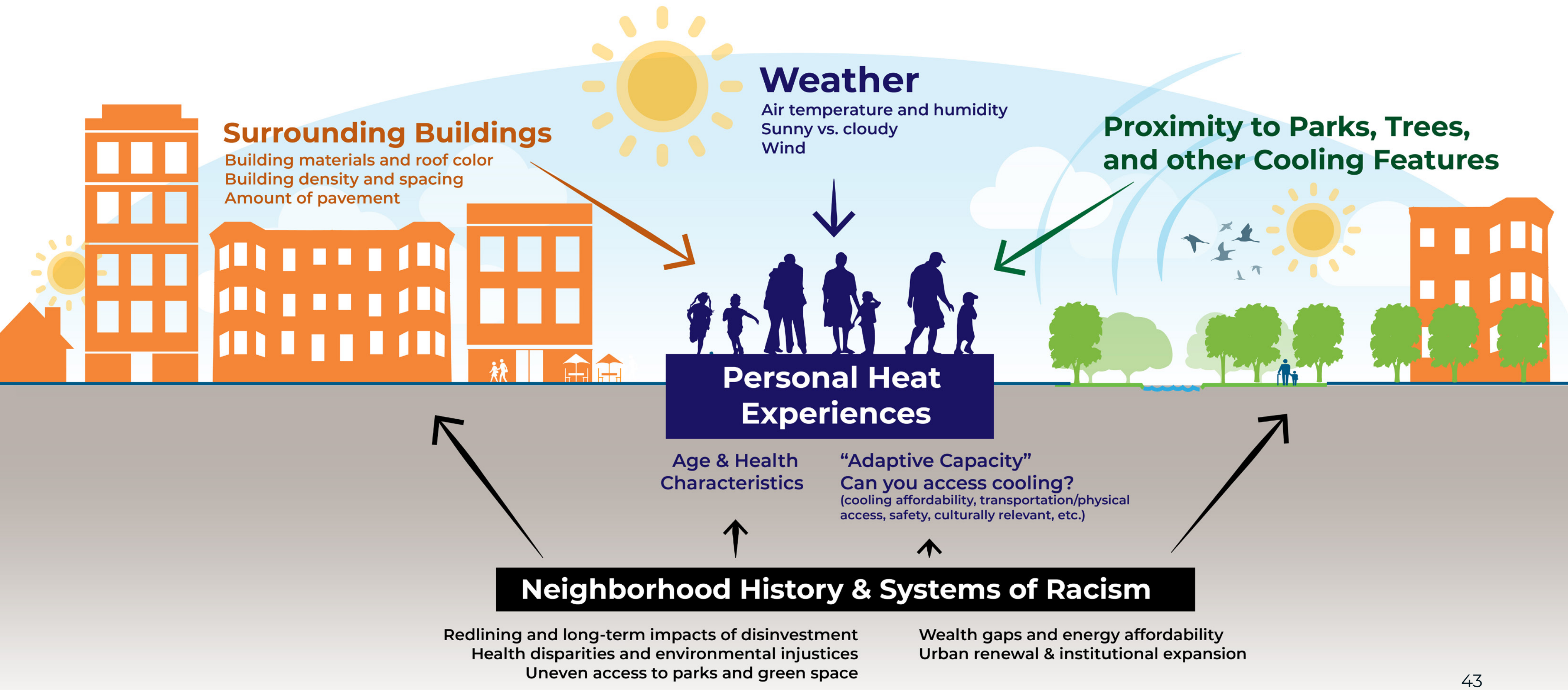
Environmental injustices and systemic racism are drivers of differences in heat experiences for both places and people.

Disparities in access to cooling and the distribution of extreme temperatures across the city have been influenced by histories of underinvestment and disinvestment that have shaped everyday life in Boston. Areas home to communities of color and immigrant communities are more likely to be temperature hotspots. These areas may also be in greater proximity to land uses that exacerbate air pollution burdens, which can exacerbate chronic health conditions, like asthma.

i Citywide Heat Analysis. See Chapter 4 Extreme Heat Risk in Boston for more information.

Heat experiences are more than just the weather.

Buildings and proximity to green and open spaces also play a role. Influencing these factors is neighborhood history and systems of racism, which places disproportionate burdens of Boston's heat on communities of color, immigrants, low-income residents, and unhoused communities.



REDLINING

The City continues to strive toward a just and resilient climate future, while adapting and responding to the changing context we live in. As we plan for future climate change, we must look back and understand how Boston's historical context has impacted current day conditions to inform our future decision making.

Between 1935 to 1940, federal officials developed and used a grading system for the Home Owners' Loan Corporation (HOLC) in cities across the nation. This system used color-coded maps to rank city neighborhoods based on perceived riskiness of providing loans for mortgages. This ranking system was highly correlated with the racial composition of neighborhoods. Communities of color, immigrant communities, and lower-income areas were typically given low grades. The lowest grading was outlined in red and labeled hazardous, meaning they were considered high-risk for mortgage lenders.[18] This practice made it difficult for people in redlined areas to qualify for mortgage loans, reducing opportunities for wealth-building associated with homeownership. The practice was formally abolished in 1968 with the enactment of the Fair Housing Act, however, many public and private investments had already been patterned based on these maps.

Discriminatory housing practices continues to impact neighborhoods today. A 2020 study that looked at more than 100 cities across the United States found that redlined neighborhoods are on average 5°F hotter in summer than areas that weren't redlined.[19] These neighborhoods, which are predominantly lower-income neighborhoods,[20] also have fewer trees and parks, and more dark pavement. These factors increase heat in the built environment.

In Boston, the neighborhoods of Roxbury, Dorchester, East Boston, and Chinatown include redlined areas. Mattapan was given a grade of "declining." In Chapter 4, the *Heat Plan* presents an analysis of the HOLC map and current day extreme temperatures to explore how the use of historical housing and real estate practices have shaped the burdens placed upon environmental justice communities in Boston today.

OTHER EXAMPLES

Examples of past planning actions that have lasting effects on health and heat vulnerability today include the following:

» Interstate construction through Chinatown elevated air pollution for residents while making access to downtown jobs easier for suburban commuters.

» The loss of East Boston's Wood Island Park for Logan International Airport's expansion in the 1960s removed an important and beloved park. Today, the surrounding area is one of the hottest in East Boston.

» The presence of bus and truck traffic in and near Lower Roxbury and Nubian Square leads to greater exposure to air pollution, and these areas have higher rates of asthma among neighborhood residents. Research studies have found a link between air pollution exposure and asthma.[21]

We know communities that contribute the least to climate pollution bear the greatest impacts of climate change. As we prepare our communities for the impacts of extreme heat, we must place people first. This means designing and implementing targeted policies and programs with and for disadvantaged and overburdened communities, lower-income neighborhoods, people with limited English proficiency, and other drivers for the disproportionate impacts of climate change.


300 Meet to Fight Artery Route Planned by Volpe
ROBERT HANRON
Daily Boston Globe (1928-1960); Oct 23, 1953;
ProQuest Historical Newspapers Boston Globe (1872 - 1979)
pg. 1

300 Meet to Fight Artery Route Planned by Volpe

By ROBERT B. HANRON

Chinese merchants and garment industry leaders and workers last night joined forces to kill the state plan to route the Boston Central Artery through their district.

More than 300 representatives of these groups convened at a hastily-called meeting in the Chinese Merchants Association Building at Hudson st. and Harrison av. to map strategy for a fight-to-the-finish battle to save their homes, businesses and jobs.

PROTEST Page 37

Boston Globe 1953; Source: Boston Chinatown Atlas

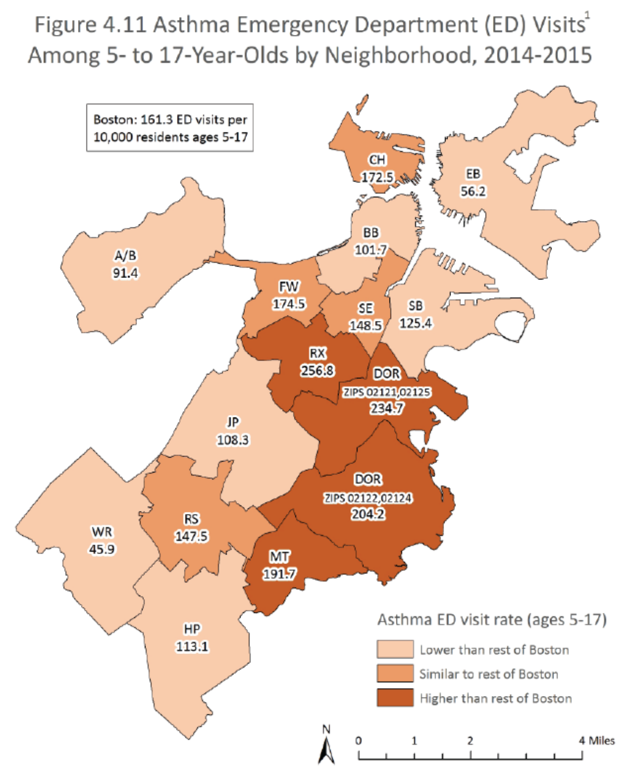
Wood Island Park in East Boston (1925).
Source: Boston Pictorial Archive

"In 1898, the Wood Island Park in East Boston opened. Designed by the famous landscape architect, Frederick Law Olmsted, the park included ball fields, tennis courts, a gymnasium, bathhouses, picnicking areas and lots of green space. On hot days, people entered the park in search of cool sea breezes beneath the huge 200-year-old elms, maples, and oak trees. Children enjoyed rolling down the hills, and swimming in the beaches. And on the weekends, families came to the park first thing in the morning; securing a spot to spend the day. In the late '60s, the park was razed to make way for airport expansion."

-East Boston Museum

"The inequitable exposure of communities of color to transportation pollution reflects decades of decisions in Massachusetts about transportation, housing, and land use. Decisions about where to place highways, where to invest in public transportation, and where to build housing have all contributed to a transportation system that concentrates emissions on communities of color."

-Union of Concerned Scientists



Asthma rates are highest in Roxbory.
Source: Health of Boston Report 2016-2017 (BPHC)

INFRASTRUCTURE VULNERABILITIES

TRANSPORTATION INFRASTRUCTURE

Extreme heat also impacts built infrastructure that residents, workers, and visitors rely on to move about the city.

Roads and Rights of Way

Concrete is susceptible to buckling under extreme temperatures due to thermal expansion.

Subway and Trolley

Additionally, heat causes steel rail tracks to expand, which stresses the ties, ballasts, and rail anchors, resulting in a heat kink that requires repairs to avoid derailments.[23] To account for these impacts, speed restrictions are implemented when temperatures reach 90°F, which can impact commute times in the summer.[24] Extreme heat also causes power lines to droop, requiring service adjustments that cause passenger delays. Further delays can result from equipment failure and reduced lifespan of necessary systems. For example, higher temperatures inside encased traffic lights and signal controls can result in equipment failure.

Heat kink along the Orange Line rail tracks
Source: MBTA

Roads buckling in extreme heat
Source: Mackenzie Huber, The Argus Leader Via AP

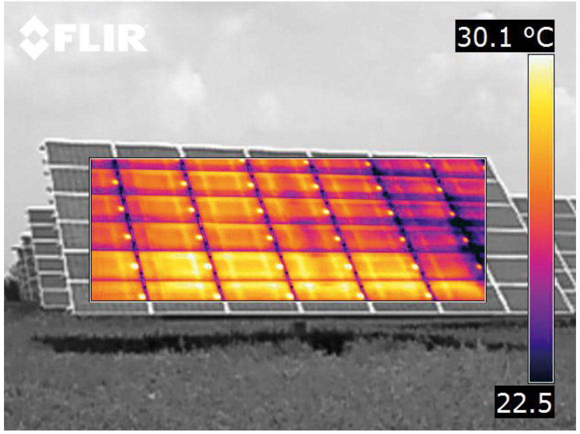
IMPACT ON TRANSPORTATION INFRASTRUCTURE

- » Buckled roads
- » Track repairs for railways
- » Speed restrictions on railways
- » Drooping power lines
- » Power outages affecting transit operations

ENERGY INFRASTRUCTURE

Energy infrastructure and the potential for heat-related power outages is also a risk that impacts heat experiences. Extreme heat can lead to increased peak summertime energy consumption, reduced transmission capacity, and decreased efficiency of solar panels.

For every 1.8°F increase above 77°F, the efficiency of solar panels is reduced by 0.1 to 0.5%.[25] Temperatures of solar panels in Boston can reach 149°F.[26] Depending on the manufacturer, utility-scale photovoltaics may experience summertime capacity reductions of 0.7 to 1.7% per one degree Celsius reduction.[27] Additionally, transmission capacity may be reduced by 1.9 to 5.8% under a business-as-usual emissions scenario, relative to 1990-2010.[28] On top of that, electricity consumption during the summer months may reach three times the average consumption rate in 1960-2000. This is due to additional cooling loads from the predicted increased number of heat waves without improving building envelope and energy efficiency.[29] The combination of these risks increases the likelihood of heat-related power outages, which can affect people's adaptive capacity, or ability to cool off using air conditioning and fans. High voltage lines are particularly vulnerable, as they are not able to dissipate heat effectively due to their thickness.



Hot solar panels
Source: FLIR Media

High voltage power lines power lines sagging in the heat

IMPACT ON ENERGY INFRASTRUCTURE

» Decreased efficiency of solar panels
» Reduced transmission capacity
» Increased peak summertime loads
» Heat-related power outages
» High voltage power lines